UBI STUDENT STUDY GUIDE

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Student Study Guide
Professional Repair and Shop Operation

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Chapter 1

Measuring Tools, Torque and Wheel Components

Objectives:

- Understand use of vernier calipers, thread pitch gauge and torque wrench
- Identify the difference between freewheel, freehub, and front hubs
- Overhaul a cup-and-cone hub set
- Identify types of cartridge bearing
- Understand wheel components

MEASURING SKILLS

A mechanic must acquire many skills, and one of the most important is the ability to accurately measure and interpret specific dimensions. The three most common types of measurements in bicycle mechanics are linear (the shortest distance between two points), thread pitch and torque.

The two tools that a bicycle mechanic typically uses to take a linear measurement are a tape measure and a caliper. Tape measures are normally used when the resolution of the required measurement is no finer than 1mm, or 1/16 of an inch. For more precise measurements, some type of caliper is generally used. Vernier scale calipers (figure 1) are probably the most common, although some mechanics prefer dial or digital models. Most calipers can be used to measure outside, inside, and depth dimensions.

Vernier calipers will be used in many hands-on sessions at UBI. Most calipers measure in both metric and inch units.

On the caliper in Figure 1, metric measurements are read with the upper scale of the main beam. It has markings for each centimeter and is broken into millimeter increments.

The sliding Vernier scale is divided into 50ths of a millimeter. The caliper should be read at the "O" of the sliding Vernier scale to obtain the whole number measurement. Observe the smaller numbers on the Vernier scale aligning with the main beam. The number on the Vernier scale that matches best with any line on the main beam will give you the 1/10th millimeter measurement. It is generally not necessary to get more exact than 1/10th mm in the bike industry.

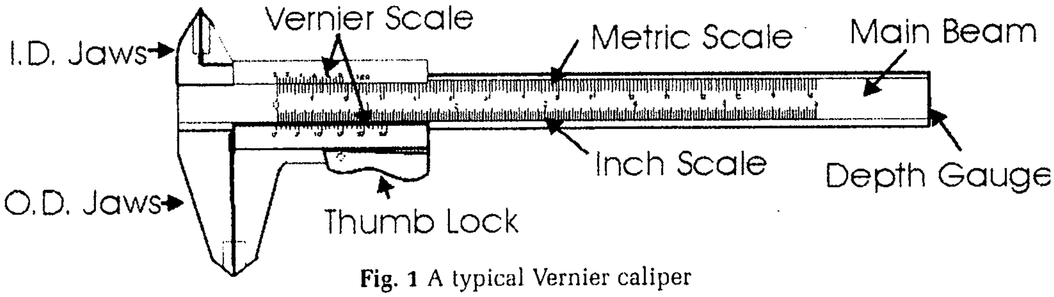


Fig. 1 A typical Vernier caliper

Notice that the lower scale on the main beam reads out to six inches in increments of twenty five thousandths of an inch and that the lower Vernier scale resolves to one thousandth of an inch. The inch scale is read in the same manner as the metric scale. However, most bicycle related measurements are read in millimeters.

STUDENT HANDS-ON:
Linear Measurement with a Vernier Caliper

Tools needed:

- Vernier calipers
- Chainring straightener

Step 1 - Make sure that the part to be measured is clean and free of any burrs or gouges.

Step 2 - Make sure that the caliper is clean and operational and that it reads zero when it is fully closed.

Step 3 - Depress the thumb knob and slide the movable jaw away from the stationary jaw to open the caliper.

Step 4 - Align the stationary jaw with one edge of the part to be measured and slide the movable jaw to the opposite edge of the part with a "clamping" motion. Verify that both the jaws are parallel to the edges of the part.

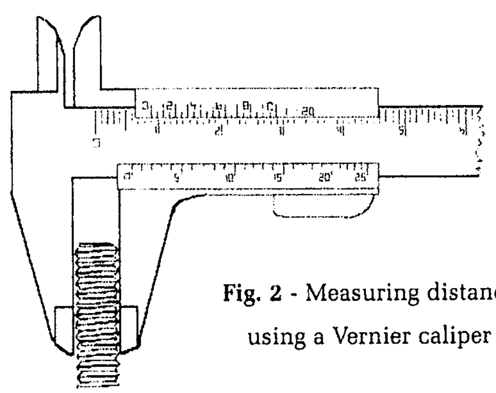


Fig. 2 - Measuring distance using a Vernier caliper

Step 5 - Look at the left hand zero on the upper Vernier scale and read how many millimeters it passes. Record the number:

_____9_____ millimeters 7

Step 6 - Sight along the Vernier scale and establish which line coincides with a line on the main beam scale. Record the best choice:

____.8____ tenths/millimeter .79

Step 7 - Add your two measurements together (example: 25 + .4 = 25.4 millimeters).

Step 8 - Repeat your measurement to verify accuracy.

Measurement Nomenclature

Once a measurement has been read, it needs to be interpreted. In order to correctly make this interpretation, you must understand some basic metrology, or measuring nomenclature.

Nominal size – This is the size stated by the engineer and/or manufacturer for general identification purposes. The actual measured size varies somewhat to allow clearance for assembly or intentional interference for a press fit. Some variations arise as a result of the manufacturing processes.

Allowance - Intentional variation from nominal size to allow easy assembly, or in the case of a press fit, intentional interference of parts.

Limits – The maximum and minimum acceptable dimensions of a part. This is usually referred to as upper limit or lower limit.

Tolerance - The specification for the total permissible variation in the size of a part. For example: a specification of 10.0mm plus or minus .2mm would allow the use of any part measuring from 9.8mm to 10.2mm (abbreviated 10.0mm +/- .2mm.)

Precision - The level of dimensional refinement to which a part is made or work is performed. Work completed to a tight dimensional tolerance is precise.

Accuracy - When a part measures within the specified dimensional tolerances, it can be considered accurate. A part that conforms to a wide dimensional tolerance, such as plus or minus two millimeters, may be technically accurate but also be imprecise.

Interpreting a measurement requires an assessment of the manufacturer's tolerances compared to the nominal size that is expected. A good example is measuring the diameter of a threaded part. The processes involved in forming threads usually results in a part that is smaller than the nominal dimension - about .1 -.2mm is typical. As you will see measurements are frequently taken to help identify a particular manufacturing standard.

Measuring Thread Pitch

Another type of measurement often taken by a mechanic is thread pitch. The pitch of a thread is measured from a point on one thread to the corresponding point on the next. For thread pitches commonly used in North America and the U.K. this is expressed as threads per inch (abbreviated TPI). SAE (Society of Automotive Engineers) threads are also expressed in TPI. Metric thread pitch is expressed in millimeters per thread (abbreviated as M).

A bicycle may have English, metric, or a combination of the two thread pitches on its various components. The simplest way to measure a thread pitch is with a thread pitch gauge.

A thread pitch gauge consists of many thin steel blades with teeth on them that match the corresponding thread pitch. Each blade's pitch is stamped on its side.

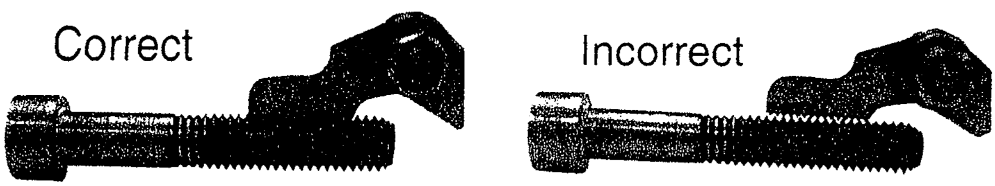


Fig. 3 - The thread pitch gauge should rest squarely on the part and must match the thread profile.

The measurement is performed by selecting a blade and placing its teeth in the threaded grooves of a part. The blade is then visually inspected to determine if its teeth match the thread profile of the part (figure 3). It may be necessary to try several blades in order to find one that conforms exactly to the threads being measured. Refer to the following chart for a listing of the most common English and metric threads found on bicycles.

Threads per Inch Common Applications (TPI)

56 - Most high quality spokes and nipples.

28 - Older axles and higher quality 1 piece cranks.

26 - Hub axles, all oversize steerer tubes, Campagnolo derailleur hangers.

24 - English and Italian bottom brackets, 1" steerer tubes, freewheels/hubs.

20 - Most pedal spindles, 14mm BMX hub axles.

Millimeters per Thread (MMPT) Common Applications

1.25 - Nut-type bottom bracket spindles.

1.0 - Miscellaneous fasteners (such as caliper brake mounting bolts, cable pinch bolts, common axles, etc.).

.8 - Bottle braze-ons, rack mounts, down tube shift lever bosses, some barrel adjusters, and 5mm bolts and nuts.

.5 - Drop-out adjusting screws, some derailleur limit screws.

When listed as a specification, typical threaded part dimensions state the nominal diameter first, then the pitch (i.e. M10 x 1.0 or 3/8" x 26 TPI), and, finally, the length.

Remember that the actual thread diameter will be one or two tenths of a millimeter or a few thousandths of an inch less than the nominal. The two examples above would read about 9.8mm x 1.0 and .368" x 26 TPI on a measuring caliper.

TORQUE MEASUREMENT

The third type of measurement mechanics must learn is torsional load applied to a fastener. This is commonly known as torque. Many bicycle components manufactured of ultra-light alloys or carbon fiber have narrow ranges of acceptable torque for safe assembly, making this measurement skill critical for a bicycle mechanic. Before you can truly appreciate how important this measurement is, you must understand what is actually happening when a fastener is tightened.

As an example, consider a very simple bolted joint consisting of two plates. A bolt passes through a hole in each plate, with a nut on the opposite side. When the nut is tightened, the two pieces are clamped together. The question is what causes this clamping force?

The element of the joint that contributes the most clamping force is the bolt. When the nut is tightened, the bolt actually stretches elastically a small amount. Since the bolt is constantly trying to return to its static length, it behaves like a spring and clamps the two pieces together. To a lesser extent, the plates are compressed like springs and also contribute to clamp the joint. This basic model is easy enough to visualize and understand. The difficulty lies in attempting to quantify the amount of preload (or stretch) applied to the fastener. Only a small part of the torque applied with a wrench contributes to preloading the bolt. This can be as little as five to ten percent! The remainder of the torque is primarily consumed by friction, which itself can be affected by a large number of factors. The next page shows only a partial list of these factors:

1. Fastener material
2. Material being clamped
3. Surface finish of threads
4. Thickness, condition, and type of plating on threads
5. Amount, type, condition, and method of application of any lubricant
6. Quality of fit between the threads
7. Hole clearance and alignment
8. Alignment of parts to be fastened
9. Tightening speed
10. Presence of washers
11. Use of locking devices or compounds
12. Diameter of the parts

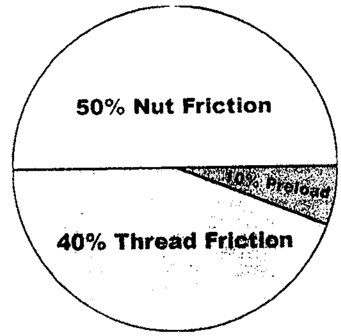


Fig. 4 - Distribution of torque as a threaded assembly is tightened.

Again, this is only a partial list. The important point is that there are many variables at work when preloading a fastener. Figure 4 illustrates a typical distribution of torque that goes into a threaded assembly as it is tightened. In this example, nut friction refers to the resistance at the surface of the nut or bolt being turned. Thread friction is the resistance between the threads of the nut and threads of the bolt. Preload is the tension applied to the bolt. Any increase in nut or thread friction comes at the expense of preload.

As an example, let's say a mechanic does a poor job of lubrication and increases the total nut friction to 55%. The only place that this energy can come from is the preload. The preload therefore goes from 10% down to 5%. This actually means a 50% loss of preload, which is what establishes sufficient and lasting clamping force.

In other words, just a 10% increase in nut friction results in a 50% loss of preload.

So what's a mechanic to do? Since there are so many factors that are difficult or impossible to control, the mechanic's best approach is to be consistent with the factors he or she can control. First, lubrication of all parts that encounter any friction is essential. Second, a professional mechanic should also measure the input torque on all threaded joints with a torque wrench. These two practices should be routine.

There are many tools available to measure the torque applied to a fastener. They vary greatly in cost as well as precision. The most commonly used tools in the bicycle industry are manual torque wrenches. Of these, there are two types - beam type and micrometer type (figure 5).

Generally, beam type torque wrenches have two scales, usually reading in foot pounds, (ft. lbs.), inch pounds (in. lbs.), and/or Newton Meters (Nm). This type of

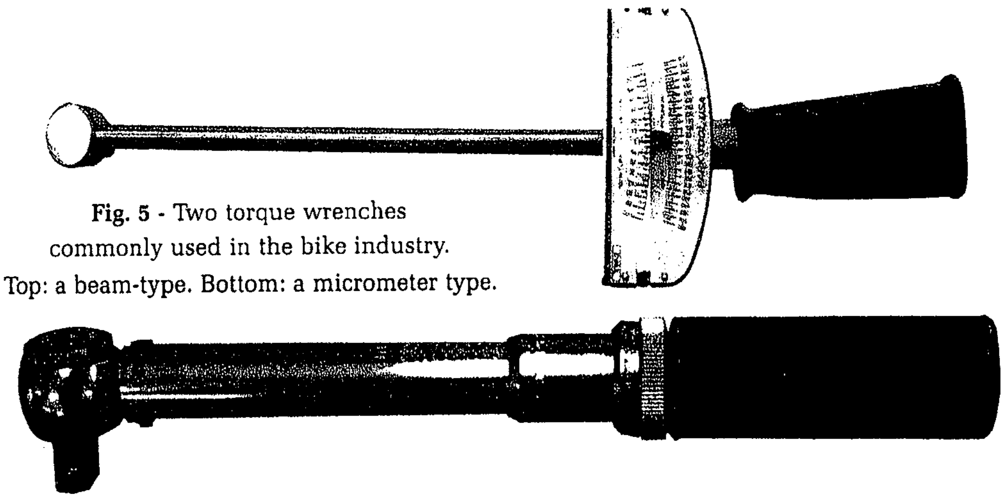


Fig. 5 - Two torque wrenches commonly used in the bike industry. Top: a beam-type. Bottom: a micrometer type.

torque wrench is less accurate for finite torque values, or narrow torque ranges. They are most accurate in the middle range of the scale. The micrometer type torque wrench is more precise and sensitive, but can also be more fragile and expensive. It should be used on smaller fasteners like cantilever or linear pull arm mounting bolts, stem clamp bolts, etc.

Most torque specifications referred to in the bicycle industry use either ft. lbs., in. lbs. or Nm as units of measure. In some cases kilograms of force per centimeter (Kgf.-cm) are used. Any unit can be converted to another by referring to the conversion chart in the appendix.

A foot pound of torque is defined as the force resulting from a pound of weight acting on a one foot lever (see figure 6).

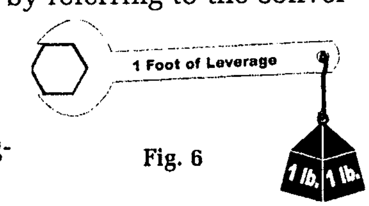


Fig. 6

The following guidelines should be observed whenever using any torque wrench.

1. Make sure the wrench has the appropriate range for the intended use.

2. Always hold the wrench perpendicular to fastener axis.

3. Grip the wrench in the center of the handle.

4. When using a beam type, make sure the handle is free to rotate on its pivot.

5. Apply gradual force on the handle until the desired torque is achieved.

6. Always use the manufacturer's recommended torque values. Many manufacturers now label torque values directly onto their components, include them with the assembly instructions, and/or post them on the tech sections of their web sites. It may also be possible to phone the manufacturer directly to request a torque value.

7. When finished using a micrometer type torque wrench, always return the handle to below the scale.

The beam type is read directly at the end of the beam and the micrometer type is preset to the desired torque and clicks when that preset value is reached.

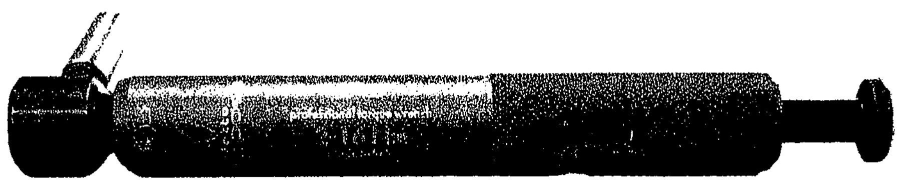


Fig. 7 Another example of a micrometer type torque wrench. This wrench is designed specifically for the range of torque values found on bicycles.

Using professional tools and procedures is indispensable for protecting your customers from mechanical failures and helping to protect yourself and your shop from expensive lawsuits. Bear in mind that it is an engineer's job to specify the proper torque value for a given application and it is the mechanic's job to follow that specification accurately. A torque wrench should routinely be recalibrated at intervals specified by the wrench's manufacturer in order to ensure continued accuracy.

HUBS

Every hub has a hub shell and an axle set. The hub shell consists primarily of the flanges and the bearing cups. The axle set is made up from an axle, bearing cones, lock washers, spacers, and locknuts.

Hub shell construction varies mainly with material, flange diameter, spoke hole count, and whether the hub will be used as part of the braking system. Rear hub shell construction also depends on whether the hub will use a freehub, a freewheel, or a single fixed cog (as in a track hub).

The least expensive hub shells are made from several steel parts that are stamped and then joined together in a process called swaging. Steel hubs are easy to recognize by the chrome plating used to prevent rust. Although hubs made with this type of shell are very affordable, they do have some disadvantages. Steel is relatively heavy compared to aluminum alloys, and corrodes easily. Probably the most significant disadvantage is the method of construction. Each flange is swaged (a process that compresses two parts together) onto the center tube to form the hub shell, and since these flanges also house the bearing cups, bearing misalignment can often result. The right flange of the rear hub is where the cogs are attached. In certain situations when extreme torque is applied to the drive train, the right flange of a steel hub can shift or slip a small amount. This shift causes a couple of problems. First is that the spoke tensions become uneven. The second, more severe and permanent problem is that the bearings and cogs become misaligned with the axle.

The spoke tension issue can be corrected, but the alignment problem is incurable. Since wheel replacement is the only practical solution, it is good to recognize this condition early on. Hubs with this problem can usually be diagnosed by checking for exceptionally tight and loose spots in bearing adjustment, similar to the symptoms of a bent axle. Another telltale sign is severe cog waver when coasting.

Most bikes sold by independent bike dealers are equipped with hubs that utilize one-piece shell construction. One-piece hub shells are almost always made of aluminum alloy that has been cast, forged and/or machined. The advantages over three piece steel construction are lower weight, higher strength, better accuracy, and improved bearing alignment.

Hub flange diameter dimension is measured on the spoke hole centers (see figure 8). This dimension varies from about 34mm for some small flange front hubs to nearly 70mm for typical large flange hubs. The vast majority of hubs have flanges that measure between 38 and 45 millimeters.

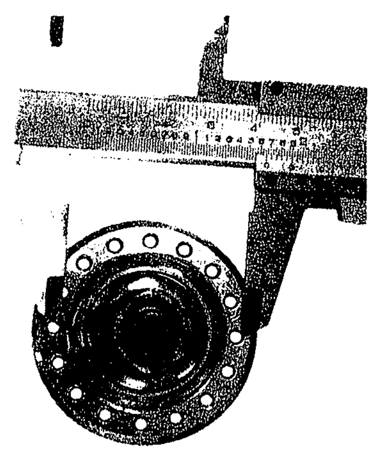


Fig. 8 - Measuring flange diameter

Some debate continues as to how the flange diameter size affects overall wheel stiffness. Suffice it to say that wheels with different diameter flanges can still have the same amount of spoke tension in them. The main reason flange diameter is relevant to a bike mechanic is for spoke length calculation purposes.

The two most common spoke hole counts for hubs and rim are 32 and 36. Many hubs and rims are available in the standard drillings of 24, 28, 32, 36, 40, and 48 holes. Fewer spokes can provide lower rotational weight and aerodynamic drag. More spokes in a wheel generally provides better reliability and requires less maintenance. However, these are not hard and fast rules. For example, wheels with fewer spokes often require heavier rims to compensate for the lower number of spokes. Such wheels could actually have higher rotational weight.

Rear hubs are easy to distinguish from front hubs because the axle is wider and

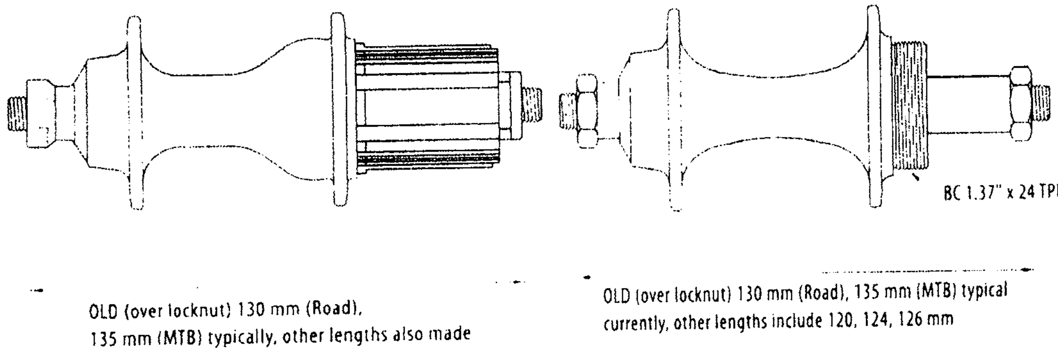


Fig. 9 - Rear hub designs. At left, a freehub. At right, a freewheel hub.

there is some obvious way to attach cogs. Axle width, or Over Locknut Dimension (OLD), will be discussed in a following section. There are two common ways to attach cogs to rear hubs. For many years, up through the early 1980's, almost all rear hubs utilized a threaded shoulder on the drive side to accept a threaded free-wheel (figure 9, right). Most modern rear hubs have an integrated freehub body on the drive side to accept a cassette of cogs (figure 9, left). A more detailed discussion of the many variations of these two designs can be found in chapter four of this manual.

The axle set consists of the axle, the bearing cones, the locknuts, lock washers, spacers and in the case of solid axles, the axle mounting nuts. Axles can be solid or hollow. Solid axles are normally found on lower end bikes where weight is not an issue but cost and simplicity are. They are also found on track hubs, BMX hubs, downhill and freeride rear hubs, and other single speed applications. Hubs equipped with quick releases must have a hollow axle to accommodate the quick release skewer.

Most hubs can be converted from solid to quick release or vice versa. The advantages of a solid axle are strength and theft resistance while the benefits of a quick release hub are that they are convenient and allow fast wheel changes. Later in this section there will be a detailed discussion of how a quick release skewer works.

Over Locknut Dimension OLD

The nominal width of a hub is measured over the outside of the locknuts and is called Over Locknut Dimension, often abbreviated as OLD. Constant evolution of hub widths raises some compatibility issues between the frame and the hub that is to be installed. The distance between the inner faces of the two dropouts should match the hub's OLD within two millimeters. If this tolerance is exceeded the residual stress that is introduced into frame and axle set may contribute to the premature failure of either, or both, components (see dropout alignment in Chapter 5). The following chart lists the most common Over Locknut Dimensions (OLD) and their typical applications.

	OLD	APPLICATION
Front	96 mm	Pre mid-70's Schwinn, inexpensive bikes
	100 mm	Common road, 9mm QR and 15mm through axle mountain
	110 mm	20 mm through axle hubs
Rear	110 mm	BMX — Coaster
	120 mm	Track
	126 mm	6 & 7 speed, early '80s road standard
	130 mm	Current road standard, older MTB
	135 mm	Current MTB standard – w/ quick release
	140 mm	Tandem
	142 mm	12 mm through axle mountain
	145 mm	Tandem, downhill
	150 mm	Downhill
	160 mm	Tandem

Shimano Axle 4mm x2 for each side

Boost – 148mm

Shimano Axle 5.5mm x2 for each side

Routine Cup and Cone Hub Overhaul

Bicycle hubs require periodic maintenance if they are to perform reliably through out their service life. The optimum interval for this service depends on a number of factors. These include operating environment (temperature, presence of moisture, contamination, corrosion, etc.), mileage, and the riding habits and weight of the rider. It is difficult to accurately recommend an optimum service interval without assessing all of the factors mentioned above, but many customers want a generic answer. A minimum recommendation for all but the most demanding riding conditions is around once a year. A good time for this service is during the bike's annual overhaul.

Ball Track Wear Patterns

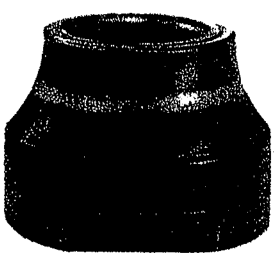


Fig. 11 -An even ball track

After a bike has been ridden even a few miles the ball tracks become established. The ball track is the area where the bearings contact the cone. This is the most important area to inspect for wear patterns that may indicate the need to replace the hub cones. The cone should exhibit a ball track that follows the circumference of the cone evenly (figure 11). Ball track wear patterns that show pitting (figure 10) or unevenness are cause for concern.

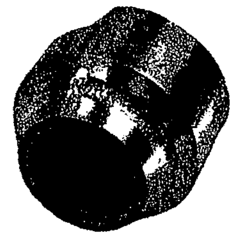


Fig 10 - A badly pitted ball track

Pitting occurs when there is too much friction between the surfaces of the ball and the cone. This causes a tiny chunk to be ripped out of the ball track, leaving a small pit. Any pitting is cause for cone replacement.

The degree of unevenness of the ball tracks is a direct reflection of the misalignment of the bearing races themselves. Since no bearing system is absolutely perfect, the amount of unevenness that is acceptable is somewhat subjective, but severe ball track unevenness in a hub is usually caused by a bent axle. This requires an axle replacement in addition to replacing the cones.

Obtaining Replacement Parts

The easiest way to ensure that all axle replacement parts are compatible with each other, as well as with the hub, is to purchase Original Equipment Manufacturer (OEM) parts that are model specific. For example, if a Shimano XT rear hub has a bent axle and a pitted cone, the best solution is to purchase a new Shimano XT axle set that comes complete with new axle, cones, spacers and locknuts.

Although there is some limited cone interchangeability between manufacturers, several dimensions must be checked and verified before attempting to mix manufacturers' cones. This can be very time consuming and still yield poor results. If mitigating circumstances leave you no choice, here is a list of what you need to check: thread pitch, cone radius, ball track diameter, cone outside diameter (dust cap clearance), integrated labyrinth seal, cone width or thickness (which affects OLD), and pressed-on dust cap dimensions.

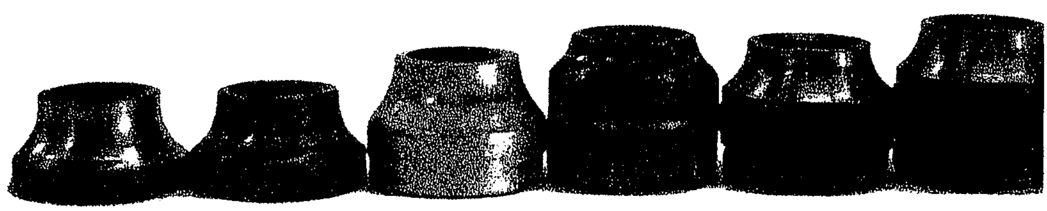


Fig. 12 - An assortment of cones for a cup and cone hub bearing assembly. Note the wide variation in dimensions.

Loose ball bearings are used extensively in the bicycle industry. Their popularity in a cup and cone design is largely due to their ability to "self align" by rolling along the curvature of the ball track. An added advantage to loose ball bearings is that they are relatively inexpensive.

There are different quality bearings which will affect ease of adjustment and wear. The grade of a bearing refers to its sphericity, or quite literally, how close the ball is to being perfectly round. Ball bearings used in bicycle components are available in only a few grades. Sphericity is measured to the nearest millionth of an inch. The materials used in these applications also vary by grade.

Carbon Steel Grade 200 = 0.000200"

Chromium Steel Grade 25 = 0.000025"

Ceramic Grade 5 = 0.000005"

Ceramic Grade 3 = 0.000003"

For each application there are different size bearings as well. The easiest method of measuring ball bearings is a Park spoke ruler. This ruler has sizing holes that you simply pass the bearing through to check its size. Unfortunately, there is no easy way to identify the grade of bearings.

Common bearing applications:

1/8"	Freehub, freewheels, and pedals
5/32"	Headsets and pedals
3/16"	Front hubs, some rear hubs and headsets
7/32"	Older Campy hubs and bottom brackets
1/4"	Most rear hubs and bottom brackets

The following overhaul procedures work well for any hub that can be described as a "standard loose ball cup and cone hub." This example assumes a rear hub. When overhauling a front hub it is also best to disassemble the non-drive side first, even though you could work on either side. By servicing the front hub in the same manner as the rear hub, it is easier to repeat the steps correctly without confusion.

STUDENT HANDS-ON:

Shimano Hub Disassembly and Inspection of Parts

Tools needed:
Combination wrench
13, 15 and 17mm cone wrenches
Clean rags
Magnet
Alcohol

Step 1 - Assess and document the current condition of the hub.

Step 2 - Remove any rubber seals, if present.

Step 3 - Disassemble the parts on the left, or non-drive side, of the axle. Remove the left side locknut, washer(s) and cone from the axle.

Step 4 - Pull the axle out from the right side (drive side) of the hub. Leave the drive-side locknut, washers, spacers, and cone on the axle.

Step 5 - Remove the bearings with a magnet.

Step 6 - Thoroughly clean all of the parts, especially the cups and the cones.

Step 7 - Inspect the axle. The most common type of damage to an axle is bending. To check this, simply roll the axle across a flat surface. The drive side cone and spacers do not need to be removed.

Step 8 - Inspect the cones for wear.

Step 9 - Obtain any replacement parts that are required.

Step 10 - Inspect the cups. Since the cups that are pressed into the hub body are not replaceable, cup inspection should be performed simply to verify that the wheel is worth the labor and parts costs of the overhaul.

Step 11 - Inspect the ball bearings to determine size, quantity and, if possible, grade.

Hub Reassembly and Bearing Adjustment

After all parts have been replaced or determined to be reusable, the hub is ready for reassembly . After reassembling the hub, making your final bearing adjustment can be a matter of trial and error. Don't be concerned if it takes you several attempts. When making the final adjustment of the bearings, there are four possibilities for adjustment:

1. Too tight - Roughness and friction will be felt when turning.

2. Too loose - Axle will feel loose with a slight click when rocked.

3. Adjustment for wheel building - Smooth rotation with no discernible tightness or looseness: "As smooth as possible with no play."

4. Adjustment for riding - A slight amount of play that disappears when the quick release skewer is tightened.

As you see above, the proper bearing adjustment of a cup and cone hub depends on whether the hub will go back on the bike or in the truing stand.

Bearing Adjustment for Quick Release Axles

When a quick release skewer is tightened it exerts compressive force against both locknuts. The axle in a quick release hub can deflect under this force. When this happens the cones are pushed closer to the ball bearings and the hub will not rotate as freely. Compensating for this compression is a little tricky, because many factors contribute to the axle's deflection. Some of these include:

Axle stiffness (material, diameter, length)

Distance between the bearings

Quick release skewer quality

Quick release skewer leverage

Lubrication (or lack of) on the skewer cam

Quick release skewer tension nut adjustment

The bottom line on quick release hub adjustment is that the wheel must be properly secured to the frame or fork and the hub must rotate as freely as possible. How much play is removed by the act of tightening the quick release skewer is most directly related to how hard it is to close the quick release skewer. The safest guideline for correct quick release skewer tension is the manufacturer's recommendation.

STUDENTS HANDS-ON:

Shimano Hub Reassembly

Step 1 - Apply a layer of grease to each cup of the hub body.

Step 2 - Install the correct size, quantity, and grade of ball bearing. Add another layer of grease sufficient to fill all voids between the bearings.

Step 3- Make sure that the cone, spacers, and locknut on the right side are properly secured. Insert the axle through the right side of the hub shell.

Step 4- Grease the threads of the left cone and axle. Thread the cone on finger tight.

Step 5- Install the left hand spacers and or washer (where applicable) and locknut. Make sure the serrations on the locknut face the dropouts. Verify that the cone is seated against the bearings finger tight only and that the locknut is also finger tight.

Step 6- Loosen the left hand cone 1/8 - 1/4 turn with a cone wrench.

Step 7- Hold the left hand cone in place with the cone wrench and tighten the locknut with the appropriate combination wrench.

Step 8- Check the adjustment. Remember, this may take several attempts. If the adjustment is too tight or there is too much play, repeat the procedure as many times as it takes to get it right.

Step 9– Reinstall rubber seals if present.

Step 10- When you're ready for a final check, have your partner double check it, then have an instructor check your hubs. If they pass the inspection, the instructor will sign them off on your Student Daily Checklist.

CARTRIDGE BEARINGS

Industrial cartridge bearings are found in many applications on a bicycle. They are commonly used in hubs, headsets, bottom brackets, derailleur pulleys and suspension pivots. Industrial cartridge bearings are made up of three main pieces: an outer race, inner race and a set of balls. The first is the outer race and it is most often made of steel and is manufactured with a smooth outer surface and a bearing race on the inside surface. The second is the inner race, also most often constructed of steel, which serves much the same duties as the outer race. It is constructed with a smooth inner surface and a bearing race on the outer surface. The third main component are the balls, which are rotating between the inner and outer races. These balls, like the races, are likely to be constructed of steel and can vary in size according to the intended use. One additional part of the bearing assembly is the sealing system. The sealing system is not considered a main component because not all cartridge bearings utilize one. The seals may be made of plastic, rubber or metal and can be held in place with a snapring or using a labyrinth configuration.

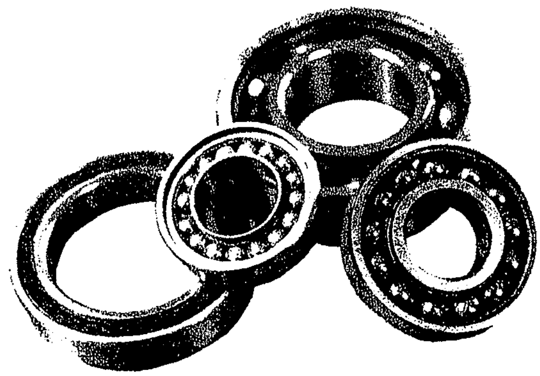


Fig. 13 - Cartridge bearings of various designs. From left: bearing with seal installed, angular contact full complement, Conrad, and full complement radial.

Cartridge bearings used in the bike industry come in three different designs. The first is the Conrad Bearing. Named after it's inventor, the Conrad bearing is the most basic design in use. The bearing utilizes a bearing retainer to evenly distribute the balls between the inner and outer races. Conrad bearings are best suited for loads that will be applied in a radial direction.

The second bearing design is the full complement (FC) cartridge bearing. The full complement bearing does not use a bearing retainer and therefore is able to use more balls within the system. The use of a higher number of balls will distribute the load over a greater area and in turn can lead to better service life of the bearing; but at the cost of higher rolling resistance.The full complement bearing, like the Conrad, is best utilized when radial loads will be encountered.

The third bearing design is the full complement/angular contact (FC/AC). The FC/AC bearing, like the full complement, does not use a retainer which allows more balls to be used. The FC/AC is unique because it is designed to accept both radial and angular loads. The angular loads are directional and the bearing has been built specifically to handle this type of load. The profile of the inner race is different from one side to the other. One of the sides will be larger, or one bearing race will extend out farther than the other. The extra material extended on the one side will better handle angular loads in a specific direction. FC/AC bearing more times than not are directional in their application, meaning the engineer of the component used an FC/AC bearing because of the load bearing capabilities. If it is going to be replaced pay close attention to the bearing that is being removed and note the orientation.

When replacing cartridge bearings three measurements are required to narrow down the options available (figure 14). The measurements are outside diameter (O.D.), inside diameter (I.D.) and the width or thickness of the bearing. Once you have the three measurements you can now look for replacement options. There are a number of options available for a given size. The cost will increase as the number of features and materials use change. Better sealing systems, upgraded grease, and stainless steel bearings are among a few of the potential upgrades.

Measuring cartridge bearings

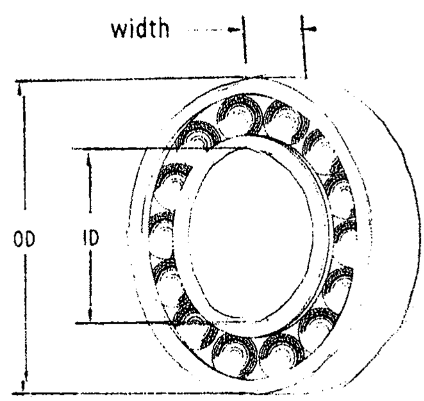


Fig. 14

The bicycle industry has also begun to use hybrid ceramic cartridge bearings. These bearings are being used because they can rotate more efficiently than a steel bearing. The inner and outer races are constructed of stainless steel while the ball bearings are made from ceramic. The ceramic ball bearings can be up to 10 times more round than a steel bearing. Ceramic cartridge bearings are being used as an upgrade to almost any bearing assembly on the bicycle currently using a traditional cartridge bearing. The use of full ceramic cartridge bearings is extremely limited due to the manufacturing tolerances that are required for proper fitting. Ceramic by nature is extremely hard which also makes it very brittle. This can lead to the bearing being damaged during installation if the materials are not perfect.

STUDENT HANDS-ON:

Cartridge Bearing Measurement and Identification

Step 1 - Using the vernier calipers, measure the outside diameters of each of the bearings in your bearing kit (see figure 15). Enter them below, largest to smallest.

Bearing 1 28 Bearing 2 28 Bearing 3 16 Bearing 4 ____

Step 2- Using the vernier calipers, measure the inside diameters of each of the bearings in your bearing kit.

Bearing 1 __12__ Bearing 2 __15__ Bearing 3 __8__ Bearing 4 _______

Step 3 - Using the vernier calipers, measure the width of each of the bearings in your bearing kit.

Bearing 1 __8__ Bearing 2 __7__ Bearing 3 __5__ Bearing 4 _______

Step 4 - Looking at each of the bearings identify whether they are Conrad, full complement, or full complement angular contact.

Bearing 1 __Ang FC__ Bearing 2 __FC__ Bearing 3 __Conrad__ Bearing 4 _______

RIMS

Early in the development of the bicycle, rims, spokes and hubs were typically made of wood. This provided a dependable, inexpensive, and easily repairable wheel to use on this increasingly popular form of transportation. In time, wooden wheels were fitted with metal bands (called tyres) to help with durability over the mostly dirt and cobblestone roads of their time, a technology also used in the horse-drawn carriages of the day. It wasn't until the late 19th century that steel rims and wire spokes became widely available and preferred for their lighter weight, better ease of repair and durability. More recently, aluminum alloy and carbon fiber have been used to manufacture rims. Aluminum alloy is the most common rim material.

Rim Materials

Wood - Although in the first half of the 20th century steel rims became widely used on lesser expensive bikes, wooden rims continued to be used by most professional bicycle racers. These wooden rims were manufactured by steaming and rolling hardwood strips (like ash, hickory or maple), and joining the ends with a finger joint. Wooden rims were extremely light. Now wooden rims are more of a historical curiosity, although a few custom makers still produce them for antique bike restorations and custom applications.

Steel – Steel's superior strength and durability quickly supplanted wood for most standard rim applications. For much of the 20th century, most of the rims on cruisers, commuter bikes, kids' bikes and entry-level "club racing" bikes were made of steel. In an effort to improve the braking performance of bikes equipped with steel rims, the braking surface was "sintered," or treated by dimpling the sidewalls of the rim, but improvements were minimal. Now, steel rims are found only on the cheapest bicycles.

Aluminum Alloy - Mavic produced the first aluminum alloy rim in 1926, although this technology was not widely available until around the 1940's. The new alloy rims were designed for the tubular (sew-up) tires used by professional racers and quickly replaced wooden racing rims due to their superior reliability and braking performance. Aluminum alloy rims were once quite expensive (and many still are), but advances in alloy technology, as well as the shift of manufacturing to Asia, has brought alloy rims to even entry-level bikes. Aluminum alloy rims have replaced steel rims because they are lighter, do not rust and provide better braking performance.

Surface anodizing on alloy rims has been used for quite some time, mainly to change the aesthetics of the silver alloy rims. Contrary to some manufacturers' marketing claims, this has done nothing to improve durability. Hard anodizing is a penetrating anodizing process that is baked into the alloy. This creates a harder rim surface and also changes its color. The drawback to hard anodizing is that it smooths and hardens the surface of the rim, which decreases the friction coefficient at the rim's braking track. In 1995, rim manufacturers began to brush or machine the braking track to improve the performance of rim brakes. Another process has been developed that treats the braking surface with a ceramic coating. This coating provides a rougher material for brake pads to work against, but also requires a ceramic-specific brake pad.

Some manufacturers also machine a wear indicator into the braking surface, which takes the form of either a colored dimple or a colored groove. This warns a user when the rim's braking surface begins to thin to the point that the rim is no longer safe to ride. These wear indicators are mandatory for all rims sold in Europe and have also found their way onto rims available in the U.S

Carbon Fiber - Carbon fiber is gaining popularity as a material for rims. Carbon fiber can be used simply as a "fairing" on an aluminum rim to help increase its aerodynamic profile, but increasingly, carbon fiber is used for construction of the entire rim. Full carbon construction can allow for a very lightweight yet aerodynamic rim. Both styles of rims are predominantly found in pre-built wheel systems from manufacturers like Campagnolo, Shimano, HED, Zipp, and Mavic. There are, however, numerous carbon rims available to the custom wheel builder. Most carbon fiber rims use a deep aero design and reduced number of spokes. Full carbon fiber rims, once available only for tubular tires, are increasingly available in a clincher design. Brake pad compatibility is an important consideration when using full carbon rims. These rims are used throughout competitive cycling, where weight, stiffness, and aerodynamics are important considerations.

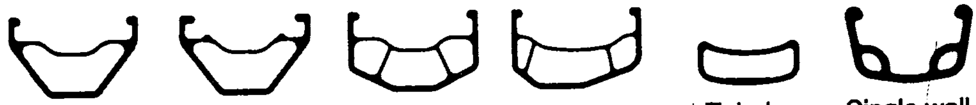
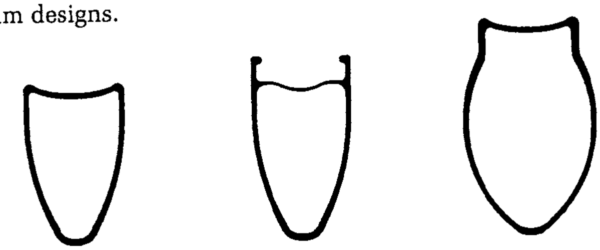


Fig. 15 - Rim designs.



Rim Designs

Most contemporary rims are made by extruding semi-molten aluminum through a specially-shaped mandrel that determines the cross section of the rim. The extrusions are formed into a spiral and then cut into hoops. The rim is then joined either by welding, or by inserting either a sleeve or pins into the hollows of each end of the rim. In some cases a combination of methods is used to join a rim. Rims are produced in one of two basic shapes designed around how the tire will be attached to the rim.

Tubular/Sew-up – Many racing wheels are equipped with tubular (sew-up) rims and tires that require an adhesive to attach the tire to the rim (see Chapter 3 for more information about tubular or sew-up tires). These rims use a concave shaped profile to cradle the adhesive and the tire casing. Tubular rims are most often used in elite-level road and track racing as well as triathlons and cyclocross.

Clincher - The more popular design for road, mountain, BMX and utility bicycles is the clincher rim. This rim design is further classified into two subcategories based on the cross section of the rim: single wall and double wall. A single wall clincher rim has an obvious "U" shape to its profile with the spoke holes at the center of the valley. The sides form the braking surface. The hook of the rim, which holds the tire's bead in place, makes up the open top. Double walled rims have an internal secondary wall to create a stronger design and support the braking walls better.

Off-center (asymmetric) design - This design places the spoke holes in the rim in a pattern to facilitate a more equal dish to the rear wheel, or a front disc brake wheel.

Disc brake specific – These rims are designed without a braking surface on the rim. Without the need of a braking surface, there is more design freedom with the rim profile. For example, a rim can be built extra wide for larger tires and increased strength, without the concern of braking performance. In some cases, a disc specific rim may be produced purely for aesthetic reasons. All things considered, a rim with braking surfaces is still suitable for most disc brake applications.

Tubeless - This type of rim is required by certain tubeless tire designs to completely seal the tire against the rim's interior wall. This prevents air from escaping from any nipple holes, or from vent holes remaining from the manufacturing process. Tubeless compatible rims also require, in most cases, a specific valve stem. These valve stems have seals or o-rings that are an integral part of the system.

Drilling Patterns

There are three configurations of rim drilling patterns available. These are designated as type "A," type "B," and center drilled rims. This designation refers to the staggered drilling for the spoke nipples. More information on how to determine whether a rim is "A" or "B" type can be found in Chapter 2.

Eyelets

Many high quality alloy rims use an eyelet to reinforce the spoke holes. Eyelets are a rivet type reinforcement that provides a wider load-bearing surface at the rim, making it less likely for the nipple to deform or pull through the rim. Some rims have double-eyelets. These reach to the secondary wall inside the rim, further increasing the support for the nipple. Eyelets are typically made of brass and provide a smoother surface for the nipples to turn against while they are being tightened. Figure 16 shows the different eyelet designs.

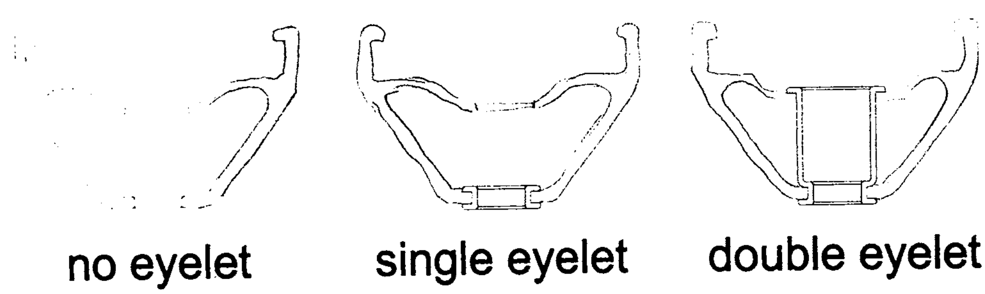


Fig. 16

SPOKES

Spokes are available in a surprising variety of designs and materials. Which spoke to use depends on the configuration of hub and rim, the intended use of the wheel, and the weight of the rider.

Spoke Materials

Wood - The earliest bicycle wheels were similar to wagon wheels, and had spokes made from wood. Wooden spokes are compression spokes, which means that they are not placed under tension when the wheel is built. Once bicycle technology moved away from wood, wheels were constructed with metal spokes used under tension.

Steel- Steel spokes are manufactured from either stainless or galvanized steel. Galvanized spokes are coated with a galvanic zinc to protect them from corrosion. These spokes are usually available in straight gauge 13, 14 and 15 gauge versions, and are common on very inexpensive alloy and steel wheels. Stainless steel is used for spokes found on higher quality bikes. Stainless steel spokes have an extended fatigue life and an excellent strength-to-weight ratio compared to galvanized spokes. They have the ability to flex with little or no structural breakdown.

Titanium - Titanium spokes are made in 14g and are as light as some heavily butted stainless spokes. One drawback to Ti spokes is that the surface of titanium is very porous. This contributes to more thread friction between the nipple and spoke ("wind-up") while tensioning, making the wheel building process more laborious. Ti spokes are expensive and not widely available.

Carbon Fiber – Carbon fiber as a spoke material is currently limited to pre-built wheel systems. There have been attempts, in the past, at creating carbon fiber spokes for the custom wheel builder. These designs were short lived because of the time involved to lace a wheel and their tendency to fail catastrophically with direct side impacts.

Kevlar - Kevlar spokes are typically used on proprietary pre-built wheel systems.

Aluminum – Aluminum spokes are typically used on proprietary pre-built wheel systems.

Spoke Designs

Straight gauge - These spokes are basically a piece of wire with one end being threaded and the other formed into the bent head of the spoke that interfaces with the hub flange. The most common – and least expensive — style of spoke is straight gauge, which uses a uniform diameter of wire throughout the length of the spoke.

Butted spokes - Butted spokes are used for wheel builds when rotational weight needs to be considered or more strength is needed in the high stress zones of the elbow or threaded end. There are three types of butted spokes: single butted, meaning that at only one end is the gauge of the wire different; double butted, in which both ends are different from the middle but equal to each other; and triple butted, when the ends are not of the same gauge nor are they the same as the middle.

Aero (bladed) - Aero or bladed spokes are used for their aerodynamic advantage and are usually made of stainless steel, aluminum or carbon fiber. Bladed spokes sometimes require the use of a slotted hub shell.

Direct Pull – Spokes are much like conventional spokes but without the j-bend or elbow. Direct or straight pull spokes need a special hub flange design to accommodate the lack of an elbow. These are most often found on proprietary pre-built wheel systems.

NIPPLES

Brass - Brass is the most widely used material for nipples because of its high strength and low friction characteristics.

Aluminum - Aluminum nipples are used when light weight is a goal, but may not be appropriate for wheels that will be used in corrosive environments. Although the anodization typically found on aluminum nipples offers some protection, unlike brass nipples, aluminum nipples will still corrode over time.

SPOKE COMPOUNDS

There are several compounds that are available to lubricate and then lock the nipple onto the spoke:

Boiled Linseed Oil - This inexpensive oil is available at any hardware store. Linseed oil will become tacky within a few hours, and this serves as a thread locker.

DT/Swiss Spoke Freeze - The wheel builder initially lubes the spoke threads with any light oil and then applies the thread locker to the nipples after the wheel is built. The oil wicks the locker into the threads and the resulting mixture forms a bond.

Wheelsmith Spoke Prep - This is a paste that is applied to the threads of the spoke prior to lacing the wheel. It creates enough friction to prevent the nipple from loosening, and will still perform after several adjustments.

Additional Reading about Measuring Tools, Torque, and Wheel Components

The purpose of this list is to provide some alternate sources to help you learn the material covered in class. There is no requirement to do any of this reading. Read as little, or as much as you would like.

Machinery's Handbook

ASM Handbook Vol. 18

Friction, Lubrication & Wear technology

An Introduction to the Design and Behavior of Bolted Joints

By John H. Bickford

Web Resources:

Cyclingnews.com:
"A primer on torque, torque wrenches, threads and fasteners"

http://www.cyclingnews.com/tech/fix/?id=torque

Chapter 1 Appendix

How-To: Campagnolo Rear Hub Disassembly

Tools needed:

5 mm hex wrenches (2)	Small flat bladed screwdriver
17 mm cone wrench	Torque wrench
Shop rags	Grease

Step 1 - Using two 5mm hex wrenches, unscrew the non-drive axle end cap and washer.

Step 2 - Loosen the set screw on the lockring 2 or 3 turns and remove the lockring

Step 3 - Lightly tap on the non-drive axle and then remove the compression ring and cone from the axle. Remove the freehub body /axle assembly from the drive side of hub.

Step 4 - To remove the freehub body from the axle, insert a 5mm hex wrench into the drive side axle end cap and, using a 17mm cone wrench, unthread (clockwise) the locknut. This is a left hand thread.

Step 5 - Slide the axle cone off toward the non-drive side of the axle. Remove the bearing retainers from hub shell, wipe clean of grease and evaluate for wear.

How-To: Campagnolo Rear Hub Reassembly

Step 1 - Lightly lubricate the axle and slide the freehub body onto the axle. Lubricate the axle threads and tighten (counter-clockwise) the locknut to 120 in/lbs. (Left hand thread!)

Step 2 - Grease the bearings and cups, reinstall the cone onto the axle. Replace the bearings and cover seal. Insert the axle assembly through the hub shell. Install the ring and thread the lockring onto the axle finger tight.

Step 3 - Adjust the lockring so that the hub operates as smoothly as possible without play. Tighten the set screw until the gap on the lockring is completely closed.

Step 4 - Install the washer onto the axle and with the 5mm hex install the end cap. Tighten to 100 in/lbs. or manufacturer's torque specification.

Chapter 2

Wheel Building and Repair

Objectives:

- Identify lacing patterns
- Load spokes into a hub
- Lace a wheel
- True and tension a wheel
- Understand basics of wheel repair

Factors Affecting Spoke Length

Spoke length is the distance from the elbow to the threaded end of the spoke. Spokes of the proper length are necessary for a quality built wheel. There are a number of factors that determine correct spoke length. These are:

- Effective rim diameter (ERD)
- Hub flange diameter/s
- Spoke lacing pattern
- Number of spokes
- Hub center-to-flange measurement

Rim diameter is a reflection of the type of bicycle the wheels are intended for: 700C, 26", 24", 20", etc. The International Standards Organization (ISO) uses the bead seat diameter in describing rim size, but this is only a relative standard for rim/tire compatibility and is therefore only a starting point. The more important measurement is effective rim diameter (ERD), which is the distance from the spoke nipple seat on one side of the rim to the spoke nipple seat on the opposite side of the rim.

The hub flange diameter is a measurement of the spoke hole center to the spoke hole center across the axle (see figure 8 on page 1-9). This is critical information in determining spoke length. A good illustration of this is to imagine a wheel with a radial lacing pattern. In a radial wheel, the spokes do not cross each other; instead, they project in a straight line from the hub flange to the rim. Any change in flange diameter directly affects the spoke length. The same holds true for other lacing patterns.

The spoke lacing pattern is a compromise between weight, stiffness and torsional strength. Lacing patterns can be divided into two main categories: radial and tangential. In a radial lacing pattern, each spoke connects in a straight line from the hub flange to the rim, never crossing with other spokes. In a tangential lacing pattern, the spokes connect to the rim by following a tangent from the hub flange, and will cross with other spokes from the same flange.

A radial pattern has limited torsional rigidity. However, because it requires shorter spokes, there is a weight reduction in the wheel. This pattern is typically used on front, non-disc wheels or on the non-drive side of the rear non-disc wheel, again as a weight saving measure. On the rear wheel, however, the drive side spokes transfer torque from the drivetrain to the rim, so the drive side typically benefits from a tangential lacing pattern. There are issues to address before deciding to build with a radial pattern. First, many hub manufacturers void their warranty if the hub is used to build a wheel with a radial lacing pattern. They do this because their hub flanges cannot withstand the tension being applied to the spokes and will potentially fail. Second, radial laced wheels can deteriorate quickly if consistent spoke tensions are not kept. Third, a radial laced wheel can be laced with all the spoke heads facing in towards the center of the hub shell, all the heads facing out, or with the heads alternating. Having the spoke heads facing inward does create a slightly better support angle for the spoke elbow, but does little for improving triangulation.

Tangential lacing patterns are categorized by the number of other spokes a particular spoke crosses between the hub flange and the rim. These patterns are referred to by the number of crosses: one cross, two cross, three cross or four cross. The three cross pattern is currently the most widely used. Its advantages are that the pattern gives the spoke elbow the most support possible, reduces weight slightly over a four cross pattern and allows for easier spoke replacement in case of repair. The four cross lacing is used mostly on tandems, loaded touring bikes and on some downhill wheels.

The number of spokes in a wheel has a greater effect on weight and durability than the lacing pattern. By increasing the number of spokes in a wheel, the space between each spoke decreases, giving the rim more support and preventing it from falling out of true or being damaged. On the other hand, reducing the number of spokes is a way to achieve lighter weight. Most common wheels use 32 spokes as a compromise between weight and strength. Many downhill, freeride and dirt jumping bikes come equipped with 36 spoke wheels, and tandems often use 48 spoke wheels. A trend in the road bike market is to use fewer spokes. The only caution here is that with fewer spokes a traditional rim has less support, so manufacturers of low spoke count wheels engineer proprietary rims to withstand the higher individual spoke tension that this design requires.

Calculating Precise Spoke Lengths

There are several methods that can be used to quickly and accurately calculate spoke lengths for any combination of rim, hub and crossing pattern. These range from the use of a wall chart and tables to computer-based systems that are based on actual product models.

Sutherland's Handbook, 7th Ed. has a series of spoke length tables reflecting popular wheel combinations. The 6th edition of Sutherland's has a manual method that can be used after taking just a few measurements and accessing Sutherland's tables and formula.

There are also calculator-based methods such as Wheelsmith's. Actually, once you understand the spoke calculation formula, you could program a calculator yourself. The most popular tools for calculating spoke lengths, however, are computer-based. These include Bike-a-log, a CD-ROM available by monthly subscription that includes brand and model-based spoke length calculator software, and a number of web-based spoke length calculators, including one on UBI's web site.

Each of these methods requires the accurate input of the spoke length factors listed on page 2-1.

Loading Spokes into the Hub

There are many methods used today to build wheels. Some involve attaching one spoke at a time. Others entail attaching the spokes in pairs. Some builders install all static spokes first and then install the remaining pulling spokes. Still others load all of the spokes into the hub first and then attach the spokes to the rim in a second step. This is the method that will be used in class. It is a particularly good method for beginning wheel builders because it is easy to catch and correct mistakes. When the wheels you build in class are finished, they should have the following qualities:

- The wheels will have a symmetrical lacing pattern.
- The wheels will have pulling spokes with their heads facing in.
- The wheels will have parallel spokes on either side of the valve hole.
- The angle and crossing of every spoke will be consistent throughout.

Trailing spokes (pulling) elbows on outside

STUDENT HANDS-ON:
Hub Spoke Loading Procedure

It is important that you read and understand each step completely before you begin it. If you do not completely understand a step, feel free to consult an instructor for personal guidance. Failure to complete each step accurately will force you to start over, losing valuable time. Please note all references to right and left in the following procedures are from the perspective of the wheel builder. The right side of the hub is the drive side, (freewheel/cassette side). The left side of the hub is the non-drive side.

Step 1 - Be sure to verify that the number of holes in the rim and the hub you are intending to build with are equal. Do not make any assumptions. Being wrong will cost you valuable time.

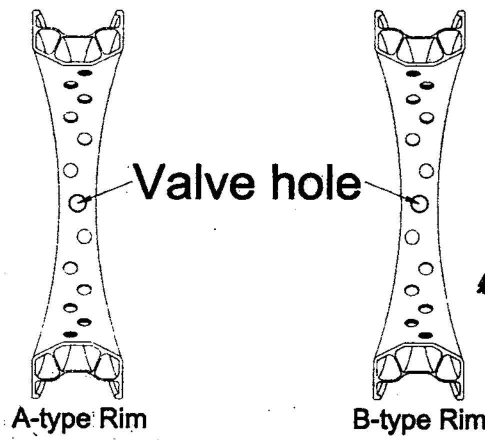


Fig. 1 - The first spoke in front of the valve hole on a Type A rim is offset to the left. On a Type B rim, the first spoke in front of the valve hole is offset to the right.

Step 2 - Determine if your rim is Type A or Type B (figure 1). Stand the rim vertically in front of you, as if you are viewing a bicycle from behind, with the valve hole at the lowest point. There will be, in most cases, a noticeable offset of the spoke holes. Locate the spoke hole just in front of the valve hole. If the first spoke hole in front of the valve hole is offset to the left, it is a Type A rim. If the first spoke hole in front of the valve hole is offset to the right, it is a Type B rim. In some cases there may be no offset to the spoke holes. If so, treat the rim as Type B, as they are the most common.

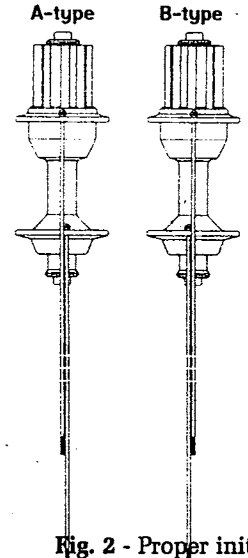


Fig. 2 - Proper initial spoke loading.

Step 3 - Hold the hub, drive side facing up. For a non disc front hub, use the hub logo to determine the drive side of the hub. The label should be readable from the rider's point of view (i.e. from left to right when viewed by the rider). Start loading spokes into the hub by selecting a spoke to install into the upper (drive side) flange. Make sure to select the appropriate length spoke. Drop the spoke into any hole in the upper flange. Make sure that the spoke head is oriented on the outboard side of the flange. Also, be sure that the spoke clears the lower flange.

Step 4 - Select an appropriate length spoke to put in the lower (non drive side) flange. To determine the appropriate spoke hole in the lower flange, position the hub vertically so that the spoke that is already inserted into the hub is facing you and is hanging straight down. You should notice that this spoke falls between two spoke holes in the lower flange. Drop the spoke in the hole on the lower flange that lies to the left of the first spoke for a B type rim or in the hole on the lower flange that lies to the right of the first spoke for a A type rim (see figure 2).

Step 5 - Starting with the lower flange, drop a spoke in every other hole, making sure to select the correct length. Now, do the same procedure for the upper flange, again making sure to select the correct length spokes.

Step 6 - Turn the hub over carefully without losing any spokes. Make sure the drive side of the hub is now facing down and all the spoke heads are also facing down.

Step 7 - Drop a spoke in every other hole in the lower flange, making sure to select the correct length spokes. Next, fill in all holes on the upper flange with the remaining spokes.

Step 8 - Verify every spoke hole has a spoke in it. Depending on how the hub is being held, verify that the spokes are oriented such that one spoke has its head above the flange and the next one has its head below the flange all the way around the hub on both flanges. Correct any discrepancies before continuing.

Preparations for Wheel Lacing

The overall quality of our wheels can be improved by properly lubricating the spoke threads and the nipple seats of the rims. Lubrication of the spoke threads allows us to attain optimum tension more easily, making for a more durable wheel which will stay true and round longer. Lubricated threads reduce thread friction to a degree which enables us to reach higher tensions without undue spoke windup or risk of rounding off the nipple wrench flats.

Failure to lubricate the threads will result in inadequate tension in the wheel, producing a wheel that will require more maintenance, be more prone to spoke failure, and in general have a shorter life.

We will also be lubricating the nipple seats of the rim. This is the area around all the spoke holes of the rim where the spoke nipples will be resting. Lubrication here will also make it easier to turn the nipple at higher tensions and allow us to more easily true and tension the wheel.

For spoke nipples, any heavy oil will work just fine. A traditional favorite is boiled linseed oil, which has the capability of later drying in the threads and acting as a thread locking agent while still retaining its lubricating qualities. There are commercial products available as well, such as DT Spoke Freeze, or Wheelsmith Spoke Prep.

To lubricate the nipple seats of the rim, a heavy grease is preferred due to its long lasting qualities. A small amount of grease may be deposited around each hole by any temporary tool, such as a cotton swab, pencil eraser, or even a spoke nipple attached to a spoke. Try to keep the grease on the inside of the rim or your wheel will get very slippery when you are trying to lace it.

Please note: All references to right or left in the following procedure are from the perspective of the wheel builder, the right side of the hub is the drive side or freewheel/cassette side. The left side of the hub is the non-drive side.

STUDENT HANDS-ON:

Wheel Lacing Procedure

Tools needed:

- Nipple driver
- Grease
- Cotton swabs

Step 1 - Lubricate the rim by applying a small amount of grease to each nipple seat.

Step 2 - Place the rim on a workbench, floor, or your lap with the valve hole closest to you. Place the hub in the center of the rim with the drive side of the hub facing up. Remember, even front hubs can be identified as having a drive side and non-drive side by orientation of the label.

Step 3 - Select a head up static spoke (head above flange) from about the 3 or 4 o'clock position on the upper flange. Attach this spoke to the first spoke hole that is offset up that lies to the right of the valve hole. For a Type B rim this hole will be the first spoke hole to the right of the valve hole and for a Type A rim, it will be the second spoke hole to the right of the valve hole (see figure 3). Thread a spoke nipple onto the end of the spoke only far enough to keep it from falling off - two or three turns will be plenty.

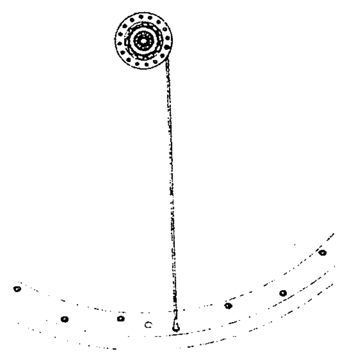


Fig. 3 - The first heads up spoke from the 3 or 4-o'clock position is attached to the first spoke hole to the right of the valve hole.

Step 4 - Select the next spoke to attach by counting clockwise from the first spoke you attached, 3 head down spokes, (skip the head up spokes). Weave this head down pulling spoke under the first spoke, skip a hole at the rim and attach. The skipped spoke hole should be offset down. Remember the weave rule - if a spoke head is facing down (towards the center of the hub) it weaves under its final cross, if a spoke head is facing up (away from the center of the hub) it weaves over its final cross.

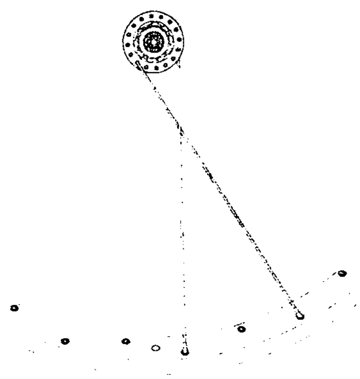


Fig. 4 - Proper weaving of the second spoke.

Step 5 - Before continuing, verify that the drive side of the hub is up. Verify a head up static spoke from the upper flange from about 3 or 4 o'clock is attached to the first spoke hole offset up that lies to the right of the valve hole.

Verify a head down pulling spoke, located in a clockwise direction from the first spoke attached, is woven under the first spoke and is attached to the rim in a counter clockwise direction from the first spoke, and there is an empty spoke hole between the two attached spokes (see figure 4). Correct any discrepancies before continuing.

Step 6 - To minimize the potential problem of trapping spokes, take a moment to orient the remainder of the spokes so the head up static spokes lie in a clockwise orientation and the head down pulling spokes lie in a counter-clockwise orientation.

Step 7 - Select the next head up static spoke in a counter clockwise direction from the other attached spokes. Attach this spoke to the next available hole that is facing up on the rim in a counter-clockwise direction. There should be an empty hole in between spokes. Install the nipple two to three turns.

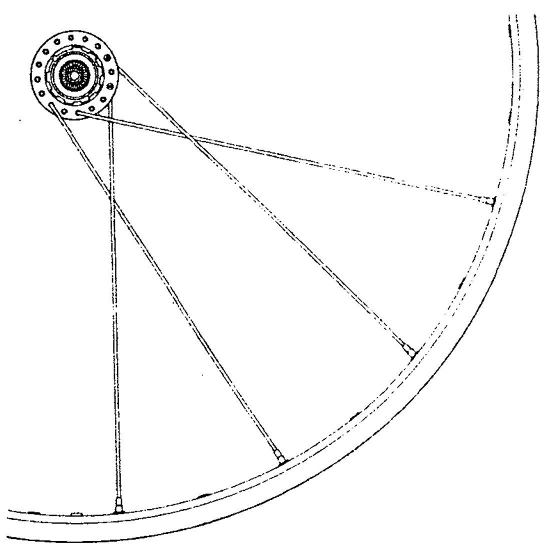


Fig. 5 After attaching four spokes, verify that there is an empty spoke hole between all spokes, and that heads down spokes are woven under heads up spokes.

United Bicycle Institute

Step 8- To select the next spoke, count in a clockwise direction from the last attached spoke, 3 head down spokes (for a 4 cross, you would count 4), skip a hole and attach the selected spoke to the rim in the next available hole that is facing up (see figure 5). There should now be four spokes attached to the rim with an empty hole in between each spoke.

Step 9- Continue this pattern for the remainder of the spokes on the upper flange. While working, periodically verify the following:

- Make sure only spokes from the upper flange are being attached to the rim.
- Verify these spokes are attached to rim holes that are only offset up. If this is true, a hole will be skipped between each spoke.
- Verify the weave is correct. Remember, if a spoke head is under the flange, it weaves under the spoke at its final cross. If a spoke head is over the flange, it weaves over the spoke at its final cross.
- After attaching all the spokes from the upper flange, verify the correctness of the lacing.

Step 10 - Carefully turn the wheel over (without losing any spokes) by cupping your hand under the lower flange and flipping the wheel over very quickly.

Step 11 - Orient the rim again so the valve hole is nearest you. Just as with the first side, you want to attach a spoke to the first hole to the right of the valve hole that is offset up. Unfortunately, on this second side, you cannot simply select a head up spoke from the 3 or 4 o'clock position to fill this hole. It won't work. You need to use a guide spoke to help you find the correct spoke to fill this hole (figure 6).

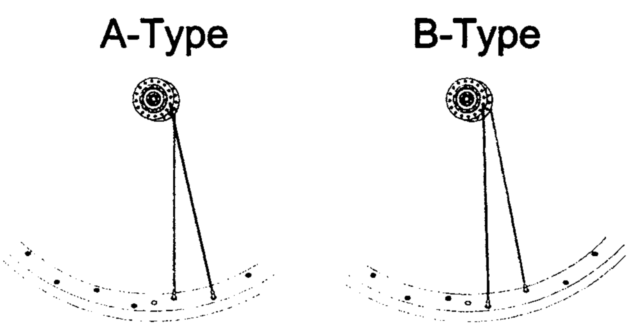


Fig.6 - Correct location of the guide spoke will depend on rim type.

Locate the guide spoke. This is the spoke attached to the rim that is located to the right of the valve hole. It should be offset down.

- **On a Type B rim** there will be an empty spoke hole between the guide spoke and the valve hole.

• **On a Type A rim** there will be no empty spoke holes between the guide spoke and the valve hole.

Follow the guide spoke to its head and carefully project a line straight up to the upper flange. Note which two spokes this projected line falls between on the upper flange - one or the other of these two spokes is the correct spoke depending on whether the rim is a Type B or Type A. For now, don't even consider the head orientation of either of these upper spokes - the correct spoke is not determined by its head orientation. To determine which of these two spokes, is the correct spoke to be attached to the rim on this second side, you must consider whether the rim is Type B or Type A.

• **For Type B rims**, the spoke that lies to the left of the projected line is correct.

• **For Type A rims**, the spoke that lies to the right of the projected line is correct.

Select the correct spoke, using the method described above, and attach it to the rim in the first hole offset up that lies to the right of the valve hole (see figure 6). As a double check, note the head orientation of the spoke you just attached relative to the head orientation of the guide spoke. These spoke heads should be oriented symmetrically - i.e., they should be a mirror image of each other. If they are not, verify that all the steps in this procedure have been followed correctly. If you have followed all the steps, then the hub was not loaded correctly for the type of rim being used. Correct the problem before continuing.

Step 12 - If everything is correct to this point, select the next spoke to attach to the rim. Moving in a clockwise direction from the first spoke attached on this side, count three head up spokes. Weave the selected spoke over the first spoke attached on this side. Remember, its head is above the flange so it weaves over its final crossing spoke. Attach the selected spoke to the rim.

Step 13 - Continue this pattern for the rest of the spokes on this second side of the rim, just like you did on the first side.

Step 14- Final Check of Wheel Lacing: Verify the correctness of the wheel lacing; then have your partner check your wheel. Finally, have an instructor check your wheel and sign it off on your Student Daily Checklist. Do not continue to work on your wheel until told to do so by your instructor.

Lateral Truing, Radial Truing, and Dishing

Once the wheels are properly laced, they are ready to be placed in a truing stand for the process of lateral truing, radial truing, and dishing. First,you must reach uniform depth of thread, and then add enough tension to each spoke to reach what is called low working tension. Next, you will laterally true the wheel, radially true the wheel, and dish the wheel. Once the wheel looks as good as you can get it, it is time to add tension to the spokes. Then you will stress relieve the wheel, possibly several times, and perform the final tensioning and truing process.

As you can see, building a wheel doesn't have to be the mystical experience that many believe it to be. By following a few simple steps in the proper order, anyone can produce a high quality, custom wheel, built to the highest standards.

Proper Sequences and Definitions of Wheel Building

The following is a more thorough definition of each of the steps you are about to undertake. All references to the wheel will be as if it were in the truing stand with the drive side on the right. A step-by-step guide will follow these definitions.

1. Uniform Depth of Thread - Begin the tensioning process by threading the nipples onto the spokes so the threads are just hidden by the top of the nipple and the nipples are square with the sidewall of the rim. This is an important starting point for the overall consistent tension of the wheel.

2. Low Working Tension - Once uniform depth of thread is achieved, tension should be added gradually, 1/2 turn at a time, until the nipples have started to seat against the rim. At this point check each spoke to ensure that all the tensions feel similar to each other on each side of the wheel and that both sides of a non-disc front wheel feel the same. Remember to keep the nipples square to the sidewall to improve consistency.

3. Lateral Truing - The process of lateral truing involves tightening and loosening spokes to cause the rim to move from side to side, ultimately creating a straight wheel. To true a rim to the left, for instance, you would tighten spokes on the left of the rim in the area that needed truing. However, if all you did was tighten spokes on one side, it would also have the effect of pulling the rim upward in that area and cause the rim to go out of round. Therefore, you must always loosen the same number of spokes on the opposite side. This will still cause the rim to move in the direction needed, but maintain consistent roundness. Remember to always tighten and loosen the same number of left and right side spokes.

4. Radial Truing - This is accomplished by tightening or loosening groups of spokes to raise or lower the rim, thereby making the rim round. If an area of the rim is bulging outward, for example, you would tighten all of the spokes in that area to pull

Black - Green - Red

it inward, including both left and right side spokes. When radial truing, it is important to tighten or loosen an equal number of left and right side spokes. If you were to tighten or loosen spokes on only one side of the rim, for instance, it would cause the rim to drift to that side and go out of lateral true. Generally at low working tension, it is best to only tighten spokes when radial truing.

If you encounter an area of the rim that has flattened inward, and loosening spokes is the only way to improve it, it is better to wait until there is more tension in the wheel. Otherwise you risk the possibility of those spokes reducing their tension too much.

5. Dishing - Dishing involves centering the rim so it is positioned exactly half way between the faces of the two lock nuts of the hub. Once the wheel is true and round, you can check the wheel with a dishing tool. If the rim is not centered accurately, tighten only the spokes on the side you wish to move the rim toward until the rim is centered. This will also add a layer of tension to the wheel, which is your next step, anyway.

6. Tensioning - Once the wheel is true, round, and dished, add layers of tension until the wheel has reached optimum tension. This is the point at which all the spokes have enough tension to keep the wheel tight, true and round for the life of the wheel. Optimum tension is reached very gradually by tightening every spoke a precise amount, usually no more than half a turn at a time. You will add layers of tension by starting at the valve hole and tightening every spoke sequentially until you return to the valve hole, continuing this process until optimum tension has been achieved. *After each layer has been added, recheck the lateral, radial true and dish before continuing.*

7. Balancing Spoke Tensions - The longevity of a wheel is determined not just by optimum spoke tension, but by even and consistent spoke tension. Even if a wheel is properly dished and true laterally and radially, an imbalance in tension will cause the lower-tensioned spokes to fatigue and fail more quickly.

Once the wheel is up to 80 - 90% of optimum tension, measure the tensions of all the spokes on one side of the wheel. If you identify a spoke with lower tension next to a spoke with higher tension, the tensions of these spokes can be balanced with little effect on the trueness of the wheel. Tighten the low-tensioned spoke one quarter turn, and loosen the high-tensioned spoke one quarter turn. Continue this procedure around the wheel. Next, verify that the wheel is still laterally and radially true, and recheck tension. Repeat this process for the other side of the wheel.

NOTE: Only compare tensions between spokes originating from the same hub flange.

8. Stress Relieving - As the wheel gets closer to optimum tension, there will come a time when the spokes will have more of a tendency to twist or "wind up" as you turn the nipple. This is due to the increase in thread friction caused by the tighter spokes. As spokes twist, they become full of stored energy. When forces are applied to the wheel, as in pedaling, the spokes unwind, releasing the stored energy, and causing the wheel to go out of true. To prevent this, you must release this energy by stress relieving the wheel as you approach optimum tension. As the wheel is being stress relieved, it will make pinging and popping sounds - the sounds of spokes untwisting. When you have finished the final fine-tuning and stress relieving, and the wheel no longer produces these sounds, the wheel is complete. You will have built a wheel that will stay true, round and dished for a long time.

STUDENT HANDS-ON:

Final Wheel Building Procedure

Tools needed:

- Truing stand
- Nipple driver
- Spoke wrench of appropriate size
- Dishing tool
- Spoke tensiometer
- Oil

Step 1 - Place the wheel in a truing stand. If you are working on a rear wheel, place the drive side on your right.

Step 2 - Lubricate each spoke by applying oil to the threads.Tighten each nipple to the top of the threads on the spoke. Uniform depth of thread is achieved when all the spokes have been tightened exactly the same amount and they have all just covered the spoke threads. Please note: the wheel must be at uniform depth of thread before you can begin the next step. Square up nipples to rim.

Step 3 - Apply low working tension by gradually increasing the tension on each spoke at 1/2 turn increments until the nipples have begun to seat against the rim. If you find one or two spokes that are looser or tighter than surrounding spokes, make whatever adjustments are necessary to equalize the spoke tension. If unsure, call an instructor over to check it with you.

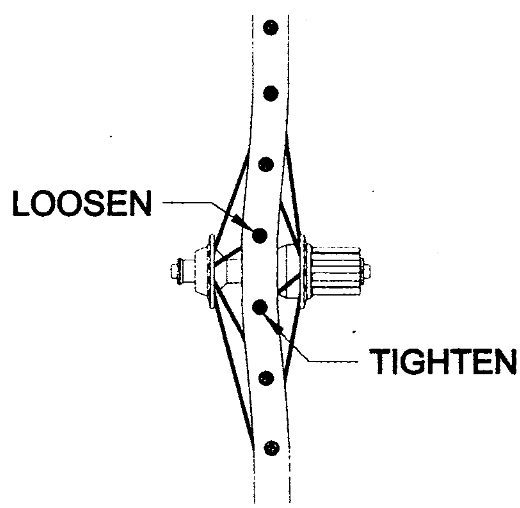


Fig. 7 - Lateral truing

Step 4 - Once low working tension has been reached, begin the lateral truing procedure (figure 7). Remember to tighten the spokes on the side of the rim that lies in the direction the rim needs to travel and to loosen the spokes an equal amount on the opposite side. It is very important your turns are consistent and you try to tighten and loosen the same number of spokes; for example, tightening two left side spokes and loosening two right side spokes the same amount.

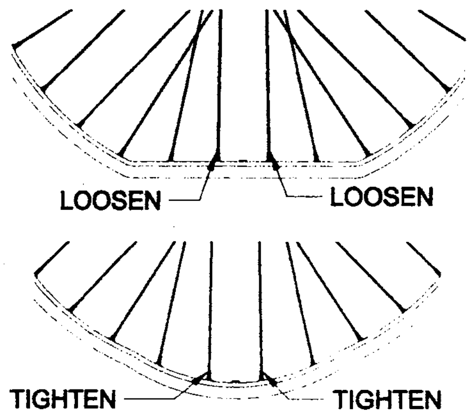


Fig 8 - Radial truing

Step 5 - Begin the radial truing procedure (figure 8). Correct any bulges (visible in the truing stand as the rim gets closer to the calipers) by tightening spokes on both left and right sides of the rim equally. Remember, if you have a flat spot (visible in the truing stand as the rim gets farther from the calipers), it is best not to loosen spokes until more tension is on the wheel. Just ignore them for now as this can be corrected in a later step.

Optimum Tension Defined

Spokes are elastic by nature. When they are stretched, they exert counter forces in the threads which are aka thread tension.

When the wheel is being ridden the spokes are constantly changing tension, due mostly to compressive forces of the rider's weight. The right amount of spoke tension keeps the nipples from unwinding under use. This is called optimum tension.

Wheels should be tight enough to stay true and round, but if you exceed optimum tension, you may exceed the rim's ability to withstand loads. This can cause the rim to fail prematurely.

Optimum spoke tension varies depending on the type of wheel and/or manufacturer specifications. However, a generally accepted recommendation in the bicycle industry for a hand built wheel is 100 kg for dishless wheels (i.e. symmetrical front road wheels) and 110 kgf for the more vertical spokes in dished wheels (i.e. the drive side of most rear wheels, or the non-drive side of most front disc brake wheels). If the optimum spoke tension is in doubt for a particular rim, contact the manufacturer.

You will be using tensiometers in class as you approach the final stages of tensioning. You should always use a tensiometer to gauge tension as accurately as possible.

Step 6 - Check the wheel with a dishing tool. To correct dish errors at low spoke tension, tighten only the spokes on the side of the rim that lies in the direction the rim needs to travel. Correcting dish error at high tension requires that you loosen the spokes on the side you want to move the rim from first and then tighten the side you need to move the rim toward. Very slight dish errors may be corrected during final truing. Any visible dishing error is twice the actual error.

Step 7 - If dish was changed, recheck lateral trueness and radial trueness and correct any errors found.

Step 8 - When the wheel is laterally true, round and dished, it is time to add tension. Beginning at the valve hole as a reference point, tighten all the spokes an equal amount in small increments - a quarter of a turn is sufficient. You should approach optimum tension slowly. At the end of each layer of tension, when you return to the valve hole, recheck trueness, roundness and dish. Correct any problem areas before you proceed. If you are very consistent with every turn, turning each spoke exactly one quarter turn, your wheel should stay true, round and dished throughout the tensioning process. If not, simply re-true after each layer of tension is added, and then continue by adding another layer of tension.

Step 9 - Once the wheel is up to 80 - 90% of optimum tension, measure the tensions of all the spokes on one side of the wheel. If you identify a spoke with lower tension next to a spoke with higher tension, tighten the low-tensioned spoke one quarter turn, and loosen the high-tensioned spoke one quarter turn. Continue this procedure around the wheel. Next, verify that the wheel is still laterally and radially true, and recheck tension. Repeat this process for the other side of the wheel.

Step 10 - As the wheel gets tighter, it is time to start stress relieving the wheel periodically. After stress relieving the wheel, recheck lateral and radial trueness, and dish, and correct any errors found.

Step 11 - Repeat the above steps until the wheel is up to optimum tension (see shaded box, p. 2-13), true laterally, true radially, and properly dished. At this point, you should hear no noises when stress relieving.

Step 12 - When you're ready for a final check, have an instructor check your wheels. If they pass the inspection, the instructor will sign them off on your Student Daily Checklist.

Final Wheel Checkout Procedure

When an instructor has signed off your wheels, disassemble them. To do this, you must de-tension them, remove all spokes and nipples, and deposit them in their designated recycling containers. Return the hubs to the instructor and put the rims in the designated area.

Truing Used Wheels and Correcting Improper Spoke Tensions

A common procedure a mechanic is asked to perform on a used wheel is truing. This can be either lateral, radial, or dish. Used wheels often present challenges because they have inconsistent spoke tensions, which can be caused by a variety of factors. Every truing procedure should begin with a basic diagnosis of the current state of the wheel to determine whether truing the wheel will be beneficial. Inspect the wheel by following these steps:

First, inspect the rim for wear, particularly if the bike has rim type brakes. Check for dents, flat spots and bulges. Determine if flat spots are the product of a damaged rim or are caused by inconsistent spoke tension.

Next, check for overall and consistent tension in the wheel by grabbing onto pairs of spokes and squeezing them gently. If inconsistencies are felt, wiggle individual spokes with your fingers to determine the extent of the inconsistency.

Inspect the area around each spoke hole of the rim. Lightweight rims may eventually fail here, evidenced by hairline cracks surrounding the hole and/or the eyelet. Also, inspect the sidewalls of the rim for excessive wear due to brake pad abrasion, evidenced by a concavity of the sidewall or shown in the wear indicator that many manufacturers machine into the sidewalls of their rims.

Inspect the condition of the spokes for signs of rust or corrosion. Look closely behind the rear cogset. You may find damage near the spoke heads caused by overshifting the chain into the spokes.

Also, inspect the condition of the spoke nipples. They should turn freely. "Frozen" nipples are due to corrosion. Also, note whether any of the nipple wrench flats are rounded off,

Finally, determine the condition of the hub. This is best done by removing the wheel from the bike. What seems to be an out-of-true wheel could actually be the result of a bent or broken axle or loose bearing adjustment. If the hub is seriously damaged it may be more safe and cost-effective to recommend a new wheel to the customer.

only mark the [illegible]

100-120 kg on short side

After thoroughly determining what is wrong with the wheel, the mechanic can make better decisions on how to proceed. Inconsistencies in spoke tension due to normal wear and tear will respond quickly to truing and the wheel will ride well again. However, if the mechanic finds significant damage to the rim or hub, it is probably time to consult the customer about the cost of repairing or replacing the wheel. The following section discusses some common wheel repair procedures.

Dealing with Rim Damage

Rim damage, usually caused by an impact to the rim, can hinder the truing process. A localized dent may just take the form of a flat spot in the rim. Often, however, the flat spot is accompanied by a pronounced widening of the sidewalls of the rim. It may be possible to repair flat spots in steel rims, but if the sidewalls are widened,the rim should be replaced, regardless of rim material.

Under no circumstances should a mechanic attempt to repair a damaged aluminum or carbon rim. Replacement is the standard practice in the industry. Depending on the quality of the components, the alternatives are replacement with a comparable factory-built wheel, or rebuilding the wheel with a new rim and new spokes and nipples.

Larger flat spots, bulges, or lateral movements in the rim, encompassing an area over many spokes, may be a product of rim damage or may also be caused by uneven spoke tensions in the wheel. The only way to know for sure is to check spoke tensions in the affected area.

Correcting Improper Spoke Tensions

The first step in correcting improper spoke tensions is to determine whether the inconsistencies are due to a damaged rim.

If the wheel has a flat spot (the rim will move vertically away from the truing stand calipers), check the spoke tension in that area with a tensiometer. If the spokes in the affected area meet the appropriate tension range, then loosening the spokes in that area should produce an improvement in roundness. However, if the spokes are already loose in the affected area, this indicates that the rim is bent and no amount of spoke tensioning or de-tensioning is going to help.

Similarly, if the rim has an area that is out of true laterally, check the spoke tension in the affected area. If the spokes on both sides are relatively consistent in tension, truing will probably correct the problem. But if the spokes on the side you wish to true toward are already tight, and the spokes on the opposite side - the side you wish to move away from - are already loose, you are probably dealing with a rim that has been bent laterally. Since the spokes are loose on the side you wish to move away from, decreasing tension even more will create a potentially dangerous wheel.

If you determine that there is no damage to the rim, you can begin to correct any inconsistencies in tension. First, starting at the valve hole, squeeze pairs of spokes to get a feel for differences in tension, or better yet, use a tensiometer. Many times, an out-of-true wheel may be caused by one or two spokes being under-tensioned compared to their surrounding spokes. Start by tightening these spokes until they more closely match the tension of the surrounding spokes. Do not be too concerned yet with lateral truing, radial truing, or dishing.

Similarly, do the same with spokes that may feel tighter than surrounding spokes. The idea here is to find a neutral ground to begin the lateral and radial truing and dishing process. If the wheel has a large degree of inconsistency, it may be better to reduce the tension in the wheel back to low working tension, and start as if you are building the wheel from scratch.

Once you have achieved more consistent spoke tension in the wheel, continue the lateral truing, radial truing, and dishing process in the usual manner, bringing the wheel to final tension. Occasionally stress relieve as you approach optimum tension.

Replacing Broken Spokes

Spokes may break because of physical damage or natural fatigue. Physical damage may be caused by an overshifted chain that has jumped from the largest cog into the spokes, or by some object that has penetrated a rotating wheel.

The most common failure though, is from fatigue. All spokes, no matter how good the quality, eventually fail due to fatigue. This is due to constant stress cycles the spokes must endure, caused largely by the compressive forces of the rider's weight.

These compressive forces cause the spokes to constantly increase and decrease in tension when the wheel is turning. The heavier the rider – or the lower the spoke tension – the greater the stress cycles on the spokes. Under these conditions, spokes will eventually lose their ability to remain elastic.

If a single spoke breaks, there is no cause for alarm. But if breakages occur more frequently, it is a sign that all of the spokes are probably reaching the end of their fatigue life, and instead of replacing them individually it is better to rebuild the wheel with new spokes.

Individual spoke replacement is a simple procedure. First, determine the proper length, gauge, and material of the replacement spoke. If it is a spoke from the rear wheel, remove the cassette or freewheel and disc brake rotor, if applicable. Then carefully insert the spoke into the hub flange so the head orientation is consistent with the adjacent spokes. Angle the spoke toward the rim hole, remembering to weave it at its final crossing (remember the rule - the weave is in the direction of its head).

One way to determine the proper length of the replacement spoke is to choose a spoke from the same position in the wheel as the one to be replaced. Measure that spoke from the elbow to the point where it contacts the rim. If the rim is steel, add 2 mm for a good estimate of proper length. If the rim is alloy without eyelets, add 3 mm. If the rim is alloy with eyelets, add 4 mm.

Now install a new nipple and start adding tension to the spoke. Be sure to use a truing stand for this. Continue adding tension to the spoke until the rim is as true as it can get between the calipers of the truing stand. Check the wheel for any other potential tension inconsistencies by using the procedure outlined previously in this chapter. Then, correct any minor lateral or radial truing and dishing problems.

Dealing with Seized Spoke Nipples

Older wheels, especially those built with cheaper spokes, may often have a great deal of corrosion in the threads of the spokes and nipples. This is due to a number of factors. The type of material used in the spoke may make it more prone to corrosion. The wheel may have been built without the use of any lubrication. The wheel may also have been ridden in harsh conditions, or the bike left outside in the elements for a long period of time.

This may make it difficult or impossible to turn the nipples with a spoke wrench. Allowing a drop of penetrating oil to flow into the nipple may be all that is necessary to dissolve the corrosion enough to break the nipple free. After applying, it may take several hours for the oil to make its way through the threads.

If this does not work, the next alternative would be to remove the nipple by clamping it with a spoke vise (Park SW-10) or, as a last resort, with Vise-Grip type pliers and unscrewing. This is always destructive to the nipple and spoke, but will usually break it free. Once free, both the nipple and the spoke should be replaced. This method is much preferred to cutting the spoke out with diagonal cutters. Cutting a spoke on a tensioned wheel can damage the hub or rim and is potentially unsafe to the mechanic.

If more than a handful of spoke nipples are frozen, it is best not to waste any time on trying to free them. At that point, it is best to rebuild or replace the wheel.

Rim Seams

Many rims are held together at the seam by a sleeve or a pin. Some are then welded and machined smooth. Quite often the seam is irregular in shape, making it difficult to true the wheel in the seam area. On sleeved or pinned rims the two spokes on either side of the seam will sometimes feel tighter than the surrounding spokes. As long as all the remaining spokes are as consistent as possible, this condition is normal and is not cause for concern.

ADDITIONAL READING ABOUT WHEEL BUILDING

The purpose of this list is to provide some alternate sources to help you learn the material covered in class, and to provide sources for further exploration of wheel building.

Sutherland's Handbook for Bicycle Mechanics (6th Ed)

Spoke Lengths, Pages 11-3 through 11-10

Sutherland's Handbook for Bicycle Mechanics (7th Ed)

Spoke Lengths, Pages 9-1 through 9 - 12

The Art of Wheelbuilding

By Gerd Schraner

The Bicycle Wheel

By Jobst Brandt

Web Resources:

Sheldon Brown / Harris Cyclery

www.sheldonbrown.com/wheelbuild.html

On-line Spoke Length Calculators:

DT/Swiss Spokes	www.dtswiss.com
Sapim Spokes	www.sapim.be
United Bicycle Institute	www.bikeschool.com

Chapter 3

Repair Stands, Tires and Tubes, Bottom Brackets and Cranks

Objectives:

- Proper repair stand use
- Tire/rim sizing and compatibility
- Pedal removal/installation
- Serviceable bottom bracket overhaul
- Cartridge bottom bracket removal

REPAIR STAND USE

The Park repair stand used in class is one of the most commonly used stands in the industry. Park offers many different repair stands in three different levels of quality - consumer, standard, and deluxe. All stands are offered as free standing floor models or bench mounted models. The consumer level stands are not intended for heavy, daily use, as you would expect in a busy bicycle shop. They are also not capable of supporting very heavy bicycles due to their lighter bases. Most shops opt for the standard models or deluxe models, which will handle the daily abuse that might be expected in a busy shop.

The Park stand is so common in the industry because for many years it was the only stand available that would withstand the daily wear and tear of a shop. Recently other manufacturers like Pedro's and Feedback Sports have released pro-level repair stands.

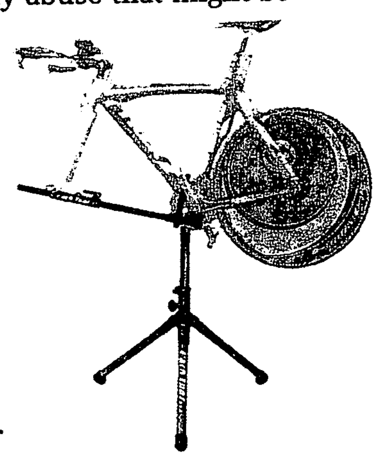


Fig. 1 The Park Tool PCS21 Euro race repair stand

The Park model PRS2 Deluxe Double Arm Repair Stand is used in the UBI classroom. Most repair stands use a radiused clamp that locks into place around the seat post. When using any stand, it is vitally important to use a minimal amount of clamping force, or damage can occur to the seatpost. Bicycles can be clamped into the repair stand using several methods - clamping onto a frame tube, clamping onto the seat post, clamping on a dummy seat post, or using the special Park Internal Seat Tube Adapter (model #ISC1).

Clamping Over the Seat Post

This is the method most used by bicycle shops. Seat posts generally have thicker walls, thus less potential damage can occur (figure 2). The only drawback to clamping over the seat post is the bicycle is positioned in the repair stand much lower, causing the mechanic to work in a bent-over position when servicing the drive train. Many shops adjust the height of their stands to compensate for this, thereby placing most of the bicycle in a more mechanic-friendly position. When clamping over the seat post, it may be necessary to raise the seat post to allow sufficient room for the clamp to fit. If you do this, be certain to mark the original height with tape or a pencil, to insure you reset the saddle to its original position. Also, make certain the seat post binder bolt is properly tightened!

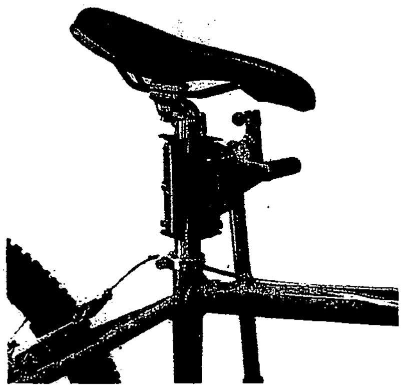


Fig 2 -The best method of mounting a bike in a repair stand is to clamp the seat post.

Using a Dummy Seat Post

Rather than utilizing the Park internal clamp, many shops keep on hand a supply of inexpensive seat posts of various sizes to be used as dummy posts. The mechanic substitutes a properly sized dummy post for the customer's seat post, then clamps the bike in the repair stand via the dummy post. This limits the chances of damaging either the frame or the customer's seat post. With some carbon and aluminum seat posts retailing for well over $100, this could be an expensive item to replace if the mechanic damages it.

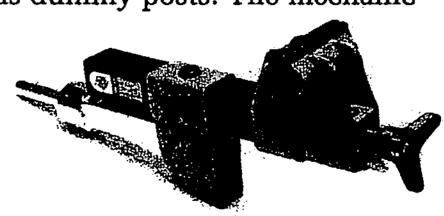


Fig. 3 - The Park Tool Extreme Range clamp

When working on recumbents or bikes with large diameter or exotic tube shapes, another clamp design may be required, such as the Park Extreme Range Clamp (figure 3). This is used in a repair stand, replacing the standard clamp.

Whatever method is used for securing the bike in the repair stand, it is always best to position the bicycle with the drive train in its most accessible position. Bench mounted models should have bikes with drivetrains facing out (away from the bench), and floor models should have drivetrains facing the bench, making all necessary tools easily accessible.

Tires and Tubes

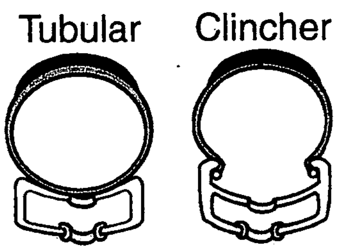


Fig 4 - Profile of tubular and clincher tires.

There are two types of tire you are likely to encounter, and they differ in the way that they mount onto the rim (figure 4). The most common is the clincher type, which is constructed with strands of wire, Kevlar or aramid molded into the inside edge of the tire, called the bead. A clincher rim has hooked edges that capture the bead when the tire is inflated. Clincher tires are used on most types of bikes, for almost all purposes. Most clincher tires use inner tubes.

Tubeless tire systems share many of the attributes of a conventional clincher tire and rim interface. Like a clincher, a tubeless tire is U-shaped in cross section, and utilizes a bead to engage the hooked portion of the rim. In the absence of a tube, however, the rim and the tire casing of a tubeless system must be specifically engineered to create an airtight seal.

In 1996, the French component manufacturer Mavic, in partnership with Michelin tires, secured a patent for the first standardized tubeless bicycle tire and rim system. Mavic calls this system Universal System Tubeless (UST). UST is an open standard, and many manufacturers currently produce UST-approved components. UST-compatible tires are available for mountain bike, road and cyclocross applications. As a standardized system, tires and rims carrying the UST logo are designed to function safely together without the need for sealants or rims strips.

Because the rim has to be airtight, UST rims cannot have spoke holes drilled through the outer wall. This precludes attaching spokes in a conventional fashion. Specially-designed spokes with integrated, externally-threaded nipples can be attached directly to threaded inserts in the inner wall of the rim. Alternatively, conventional spokes may be threaded into nipples held in place by collars in the inner wall. To allow inflation of a tubeless tire, a special sealed valve is threaded into the valve hole. If the casing of a tubeless tire is punctured, this valve may be removed and an inner tube installed in its place.

On a traditional clincher rim, the hooked portion of the rim need only support the bead of the tire and the pressure exerted by the tube. On a UST system, however, the rim and tire bead interface must be airtight. In cross-section, the profile of a UST rim shows pronounced ramps inboard of where the tire bead interfaces it (Figure 5). This seals the system and helps prevent the bead from disengaging under lateral loads. The bead of a UST tire, in turn, must be designed and molded to precisely match the shape of the rim interface. For tubeless road applications, the higher operating pressures require that the tire bead be further reinforced to prevent it from stretching and blowing off the rim. Because of the rigidity of carbon fiber, it is often used in place of aramid fibers as a bead material for road tubeless tires.

In addition to the bead, the tire casing must also be modified to allow it to hold air effectively. Conventional clinchers do not have airtight casings, making them inappropriate for tubeless applications. UST casings typically incorporate butyl rubber into the internal wall. Punctures in the casing of UST tires can be patched from the inside using the same patch kit one would use to patch a tube.

Shore A Scale

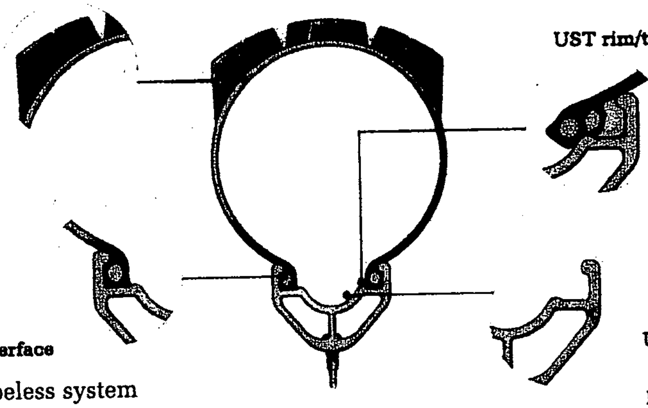


Fig. 5 UST tubeless system

Image courtesy of WTB

Tubeless systems have several advantages over a traditional tubed system. Chief among these is the ability to run lower inflation pressures without the risk of pinch flatting. A pinch flat is an impact puncture caused when an object pinches the tube between the rim and the casing, resulting in two distinctive “snake bite” holes opposite one another on the tube. Although impacts from sharp objects can still damage the casing on tubeless tires, pinch flats are eliminated. By running lower inflation pressures the contact patch of the tire is increased. This results in improved traction, control, and greater comfort.

Another potential advantage of tubeless systems is reduced rolling resistance. With a tubed system, friction is created between the tube and the tire casing as the tire deforms under load, creating additional rolling resistance. By eliminating this source of friction, rolling resistance is minimized, potentially creating a more efficient wheel.

Despite these advantages, tubeless systems do have potential drawbacks. Because the casing must be reinforced to retain air, UST tires are typically heavier than comparable clinchers. This weight penalty may negate any savings conferred by the lack of an inner tube. In addition, tubeless tires can also experience a sudden loss of air when severe lateral loads compromise the seal between the tire and the rim. This phenomenon, often called “burping”, is associated with hard cornering, and may be more pronounced when narrower rims are paired with larger volume tires.

In recent years there has have been a proliferation of tubeless conversion kits designed to allow a rider to adapt non-UST rims and tires for use without an inner tube. Typically, these conversion kits include special rim strips to seal the spoke holes in the outer wall of the rim, as well as a sealant to help seal the tire/rim interface and to allow the tire casing to retain air. Because a conversion system does not utilize a standardized tire and rim interface, there is no guarantee that a given tire and rim combination will hold air and thus function safely. As such, tubeless conversion kits should be approached with extreme caution.

Some manufacturers produce tires labeled as "Tubeless Ready", or some variation thereof. Although these tires may have bead profiles which match UST tires, they often lack the butyl casing required to be designated as true UST. This makes the tire lighter, but requires the addition of some kind of sealant to create an airtight system.

Sealants used in tubeless ready systems and tubeless conversion kits are typically either latex-based, or compromised of minute fibers suspended in a matrix. Sealants have the additional benefit of preventing air loss in the event of small punctures in the casing. For this reason sealants are sometimes used in true UST tires. Latex-based sealants will harden over time, and can pool into a solid mass after prolonged storage. This can create a potentially unsafe imbalance in the tire. It is important to note that ammonia and other chemicals in some sealants may degrade some tire casings, increasing the likelihood of a catastrophic which may cause a failure. Consult the tire manufacturer before installing any sealant to ensure compatibility.

The other tire type is called a tubular, or sew-up, tire. These tires have their inner tube sewn inside the tire casing, and the tire is glued on to a beadless rim. These tires have the advantage of being light, as they don't use a bead, and the rim construction likewise does not need to allow for the tire bead in order to secure the tire to the rim. Clincher and tubular systems are not compatible.

Prior to the late 1980's, the available clincher rims and tires could not approach the light weight and supple ride of tubulars. The performance of clinchers has since improved considerably, although tubulars are still extensively preferred in the pro ranks. Tubular tires also remain popular for track, cyclocross and triathlon racing.

Tire Materials

The components of a tire are the casing, tread, and in the case of clinchers, the bead. The casing is the woven fabric to which the tread is bonded. The casings are usually made of cotton or nylon fibers, but Kevlar can also be used. High quality tubular casings are made from silk. The thread count of the fabric's weave is another element to consider. Expressed in threads per inch (TPI), a higher thread count is generally preferable, because it allows the tire to conform to the ground better, resulting in a more constant contact patch area. This gives the rider a supple ride, better traction and less rolling resistance. Although thread count is usually stressed more in advertising, the casing material itself also affects ride and durability.

The tread itself may be made of natural rubber or petroleum-derived synthetic like styrene-butadiene rubber. Filler materials are also added — carbon black to add strength and stiffness and waxes to prevent oxygen deterioration. The hardness of rubber is measured with a durometer, and assigned a number between 10/A (softest) to 90/A (hardest). Most bicycle tires measure around 60/A.

Tread pattern on road bike tires is largely inconsequential. A completely smooth tread gives the best traction and least rolling resistance. This holds true even in wet conditions. Bicycles do not hydroplane as cars do and therefore do not require sipes to displace water. Most tires do have some sort of tread pattern, though. This can work well as a wear indicator.

The tread pattern on mountain bike tires, on the other hand, can greatly affect performance. Different terrain and/or riding conditions call for different tread patterns. The tread pattern may be different for front or rear tires, as well. Front tire patterns are designed to optimize cornering and braking. Rear tire treads are designed to assist in climbing traction as well as cornering and braking.

Touring, commuter and cyclocross tires have characteristics of both road racing and mountain bike tires. These tires are designed with tread patterns that give some off-road traction but still retain acceptable rolling performance on pavement. They are typically much wider than road racing tires and have thicker treads to improve durability and handle heavier loads. Cyclocross tires also have tread designs similar to mountain bike tires for better cornering and traction in the muddy conditions often found in a cyclocross race.

Many off-road tires (and some road tires) are manufactured with directional treads. The manufacturer's recommendation for rotating direction will be marked on the tire casing, and should be followed when mounting the tire.

The bead of a clincher tire may be made of steel wire, Kevlar or aramid. Kevlar bead tires have the advantage of being lighter, stronger, and foldable. These benefits carry a price tag, however. Kevlar bead tires may cost twice as much as their wire bead counterparts.

Tubes

Bicycle inner tubes are typically made of butyl rubber, a synthetic rubber made from isobutylene and isoprene that exhibits superior air-retention capabilities. Tubes may also be made of latex, which is prized for its lightweight and suppleness. Latex tubes are quite expensive, and don't retain air as well as butyl rubber which explains their relative rarity.

Other tubes have features to make them resistant to flats. These include thorn resistant (often marketed as "thorn proof") and self-sealing tubes. Thorn resistant tubes are simply butyl rubber tubes with thicker walls. Although they are less prone to flats than standard tubes, they carry a severe weight penalty. Self-sealing tubes are standard dimension tubes that have a sealing compound inside them. The centrifugal force generated while riding evenly distributes the fluid in the tube. When a thorn or other object penetrates the tube's inner wall, the sealing compound fills the hole. This type of tube is effective against small punctures, but they're also quite heavy and messy to deal with.

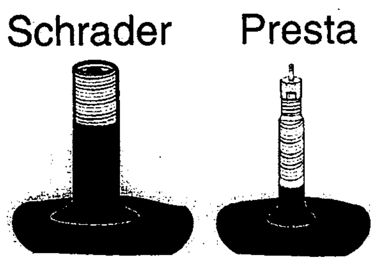


Fig. 6 - The two most common types of tire valve.

Another option for flat protection is a tire liner, which is a strip that goes between the tube and tire. These are usually made of thick plastic, but lighter weight versions are available.

When selecting a tube you need to consider its size and valve type. The tube size must correspond to the tire diameter and width. It is better to err on the narrow side than try to use a tube that is too wide. The wide tube will be difficult to insert and will be crowded in the tire.

The two valve types in use in the U.S. are the Schrader style and Presta style (figure 6). Schrader valves are still dominant on kid's bikes, many mountain bikes and some lower end road bikes. These are the same as those used on automobiles. However, it's always best to use a lower volume pump designed for bicycles when inflating a bicycle tube, even if it has Schrader valves. Service station compressors designed for auto tires push too high a volume of air, and this can lead to a blowout.

With narrower rims, however, the size of the hole required to fit the Schrader valve takes away too much material from the rim, compromising its strength. The solution is to use the narrower, Presta style valve. Presta valves have a built-in nut that must be loosened to inflate the tube, and screwed back down before riding the bike. They also require a different pump fitting than Schrader valves, although adapters are available to use a Schrader pump on a presta valve, and vice versa. Most bicycle pumps come with heads that fit both Schrader and Presta valves.

A third type of valve, the Dunlop valve, is almost never seen in North America but is common in Europe and Asia, especially on commuter bikes. The Dunlop valve is wider than a Presta valve, but can be inflated using a Presta pump head.

Tubeless wheel systems use a stand-alone valve unit. This valve unit serves two purposes. The first, of course, is to allow the inflation of the tire. The second is to seal the rim to prevent loss of air. Most of these valve units consist of a Presta or Schrader valve with a grommet that matches the profile of the rim's valley, an O-ring and a locknut to seal the rim.

extruded more consistent

Rim Strips

Rim strips are necessary to shield the inner tube from spoke nipples and spokes protruding inside the rim. After-market rim strips are made of cloth, rubber, or polyurethane.Rim strips are available in different widths to fit different rim sections. If a rim strip is too wide, the excess rides up the rim trough and keeps the tire from seating properly. If it is too narrow, the tube will not be adequately protected from the spokes. Some tubeless wheel systems do not require the use of a rim strip, because these systems are designed so the nipple threads directly into the rim instead instead of passing through both walls of the box section.

Tire and Tube Service

Flat tires are a fact of life. In a shop, you're more likely to see a bike come in for a flat repair than for any other service. Flats can be caused by a puncture from road debris, but just as often the culprit is an under-inflated tire. Usually called pinch flats, such failures are caused by the compression of the tube between the rim and the object that the rim hits. The telltale sign of a pinch flat is two holes opposite one another on the tube. This distinctive pattern is often called a "snake bite." Again, it can be avoided by proper tire inflation.

Another type of failure is a blowout. This happens when the tire cannot hold the tube in place, and part of the tube escapes. Tube blowouts can also occur if the tire's sidewall is excessively worn, or if the tire was mounted improperly. Some rim and tire combinations fit too loosely, which can cause the tire to roll off the rim, again resulting in a blowout.

Tire levers are the only tools that should ever be used to remove a tire, and then only if the tire/rim combination is too tight. Otherwise, strive to remove tires with your hands to prevent accidental damage to a tube with a lever. If levers are necessary, use plastic, or plastic-covered steel tire levers, as bare steel levers can damage both tubes and rims. The one exception would be downhill tires that may require the use of steel motorcycle levers.

STUDENT HANDS-ON:

Tire and Tube Removal

Tools needed:
Tire levers

Step 1 - Place bike in repair stand. One bench partner will work on the front wheel, the other on the rear.

Step 2 - Shift the rear derailleur into high gear (smallest cog). Open the brake quick-releases (on a caliper brake), or disengage the straddle wire (on a cantilever or linear pull brake) to allow the tire to pass through.

Step 3 - Open the wheel's quick release. If removing the rear wheel, rotate the rear derailleur's body clockwise so the guide pulley clears the cog. Allow the wheel to drop out.

Step 4 - Deflate the tire completely. Squeeze the sides of the tire together, and push the tire down into the trough of the rim. Hook one tire lever under the edge of the tire, and then pull the tire over the rim. Attach the opposite side of the lever to a spoke, then move down a couple of inches and hook a second lever under the same bead. Once a few inches of the tire have been pulled over the rim, you should be able to pull the rest of the bead off without tools.

Step 5 - Remove the tube from the tire and remove the tire from the rim.

In a shop, it isn't necessary to take the tire off unless you are replacing it or want to inspect it for damage. If the tire is not being replaced, be sure that it is free from any debris that may have caused the flat. The most efficient way to accomplish this is by running your hand along the inside of the tire. Be careful doing this, however, as you could be injured by any sharp road debris embedded in the tire casing. Another option is to use a piece of tissue paper and run it on the inside of the tire. If there is any debris lodged in the tire a piece of tissue paper will snag on the debris. Once the tube is out of the tire, most shops simply dispose of it and install a new one. While a properly patched tube can be as reliable as a new one, the labor required to patch a tube is usually too much to justify doing so. Further, it is difficult for a shop to guarantee a patch job.

To install a new tube, first inflate it just enough to give it shape. Coating the tube with a little talc at this stage is a good idea. Simply shake a little talc into your hand and pull the tube through it. Talc will allow the tube to move around inside the tire and find its proper place. The use of talc also minimizes the risk of catching the tube between the bead and rim when mounting the tire.

Tire and Rim Compatibility

When replacing tires it's important to understand the distinction between different tire and rim standards. Although there are only a few common sizes, there are many other dimensions that you may encounter. The fact that the sizes often differ by only a few millimeters, and may be quite similar in their sidewall markings, further complicates matters. When in doubt, consult Sutherland's Handbook for Bicycle Mechanics, 7th Ed., Chapter 10.

BSD	Metric	NA/Brit	Tire ISO	Applications
630		27"	30-630	Older road bike size
622	700C	700C	47-622	Most common road bike size, 29" MTB
584	650B	27.5	58-584	MTB, Touring, commuting
571	650C	26x1	20-571	Triathlon, time trial, smaller road bikes
559		26"	52-559	Mountain bikes
507		24"	44-507	Cruisers, downhill, small MTB
406		20"	44-406	BMX, some kids bikes
305		16"	44-305	Kids bikes

The important measurement to consider when determining compatibility is the rim's bead seat diameter (BSD). This is the diameter on the rim at the point where the tire bead sits. In order to fit properly, the tire's bead diameter should match the rim's bead seat diameter exactly. Both bead diameter and bead seat diameter are expressed in millimeters. Other measurements you will see on a tire are its width, expressed either in inches or millimeters, and its nominal diameter, expressed usually in inches, but occasionally in metric designations like 700c.

The table above shows some of the most common tire sizes and bead seat diameters you will encounter, as well as their typical applications. Note that there may be more than one designation for each bead seat diameter: a metric size, a North American/British size, and an ISO designation. Note also that there are some North American/British designations that appear to be the same size, but actually have different bead seat diameters.

In an effort to simplify the maddening task of keeping all of the sizes straight, many manufacturers now emboss the International Organization for Standardization (known by its acronym, ISO) designation on their tires. The ISO size of a tire is expressed as two numbers: the tire's width (in millimeters) followed by its bead seat diameter (in millimeters). Therefore, a 700C tire with a width of 28mm would have the ISO designation 28-622. In the table on page 3-9 the width designation (the first number) in the ISO column is for a typical tire width, but that number will vary.

STUDENT HANDS-ON:

Tube and Tire Installation

Tools needed:

Tire levers

Pump

Step 1 - Install one bead of the tire onto the rim, leaving the other bead hanging off the rim while you replace the tube. If the tire has a directional tread, make sure it is mounted according to manufacturer's specifications. If the tire has a label, align the label with the tube's valve.

Step 2 - Carefully fit the valve into the valve hole on the rim and add just enough air to the tube to give it some shape. Install the tube in the tire. Once the tube is in place, begin to push the second bead onto the rim. Start at the valve and work your way around with both hands until the tire is completely seated on the rim.

Step 3 - Check around each side of the rim and make sure the tube is not caught under the tire bead. Inflate the tire to about 30 PSI for a road bike and 20 PSI for a mountain bike. Check again that the tire is seated properly, and that the valve stem is still straight. If no corrections need to be made, continue inflating the tire until you have reached the manufacturer's recommended pressure.

Step 4 - Place wheel completely in dropouts and close the quick release according to manufacturer's specifications.

Step 5 - Clean the braking surface with a clean rag and alcohol. Check brake and derailleur adjustments.

Step 6 - Have an instructor check your bicycle. If it passes the inspection, the instructor will sign it off on your Student Daily Checklist.

Pedal Threads

There are two sizes of pedals spindles currently being used in the bicycle industry - 1/2"x 20 TPI and 9/16" x 20 TPI. These are the dimensions used for the spindle which threads into the crank arm. The national standard for 9/16" x 20 TPI is generally referred to as English or Italian and the standard for 1/2" x 20 TPI is referred to as American. English and Italian standard pedals are designed for cotterless cranks and American standard pedals are designed for one piece cranks (often referred to as

Pedal Thread Standards

ISO Primary	1/2" X 20 TPI
ISO Alternate	9/16" X 20 TPI
English	9/16" X 20 TPI
French	14mm X 1.25mm (obsolete)
Italian	9/16" X 20 TPI
USA	1/2" X 20 TPI

Ashtabula cranks or OPC). The French standard seen in the listed chart is obsolete and has not been used on bicycles imported into the US or Canada since the mid 1970's. For additional information about pedal thread standards, consult Sutherland's Handbook 7th Ed., page 2-2.

Thread direction is consistent among all standards. Right side pedals have right hand (clockwise) threads, and left side pedals have left hand (counter clockwise) threads.

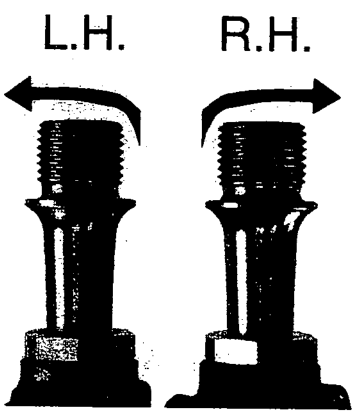


Fig. 7

Most pedals have the appropriate "R" and "L" inscribed onto the spindle wrench flat area, or on the end of the threaded post. If a pedal is not clearly marked, the thread direction can be identified by holding the pedal with the end of the threaded post facing up (figure 7). Note the slight angle of the threads. The threads will slope upward in the direction of their travel, angled toward the end of the threaded post. A right pedal thread (right hand thread) will slope upward to the right and a left pedal thread (left hand thread) will slope upward to the left. The pedal will then be screwed into the crank arm in the direction of the thread.

Pedal Removal

Many pedals have a wrench flat machined into the pedal spindle on the outboard side of the crank arm. In this case, the appropriate tool for pedal removal and replacement is a specially designed pedal wrench. A pedal wrench is very long, providing good leverage, and also thin, to allow adequate clearance between the crank arm and pedal. Many pedal wrenches come with more than one size of wrench flats, commonly 15 mm and 9/16", which fit the vast majority of pedals on the market.

Other pedals are removed using a 6 mm or 8 mm hex socket machined into the end of the spindle, accessed from the inboard side of the crank arm. In this case, removal and installation require only the correct size hex wrench.

CRANKS AND BOTTOM BRACKETS

The crankset is the heart of the bicycle, transferring power from the pedals to the chain and ultimately to the rear wheel, moving the rider forward. Crank arms must be able to withstand a great deal of torque and rider weight, transferring sufficient power without losing energy to excessive flex. For this reason, crank arms are one of the heaviest components on the bicycle. When designing high-end crank arms, every effort is put into making them as light as possible without sacrificing strength. This usually means the use of expensive materials to produce the strongest, stiffest, yet lightest crank arms possible. Crank arms are designed in one piece, two piece and three piece configurations.

One Piece Cranks

These are found primarily on BMX bikes, cruisers and inexpensive mass-market bicycles. The left and right crank arm and bottom bracket spindle form one complete unit. The spindle part of the crank is threaded on both sides to receive the cones of the bottom bracket assembly. They are made of steel and are heavy. One piece cranks usually have a single chainring attached and are designed to accept 1/2" x 20 TPI pedals. Crank arm lengths are sized in inches.

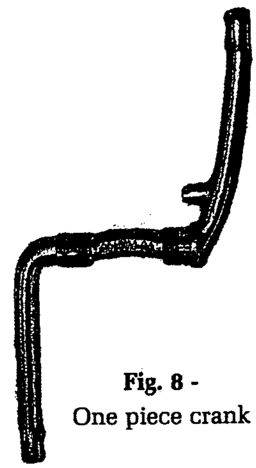


Fig. 8 - One piece crank

Bottom brackets for use with one-piece cranks use the same type of cup and cone bearing system that you've seen throughout this class (see figure 9). In this case, the cups are pressed into the bottom bracket shell, rather than being threaded like those of a three-piece crank bottom bracket. A fixed cone is threaded onto the right (drive side) side of the crank arm, and an adjustable cone is threaded onto the left (non-drive side) of the crank arm. A keyed lock washer and locknut secure the adjustment. It is important to remember that the left side of the crank, along with the adjustable cone and locknut, are left hand threaded. These bottom brackets, being significantly less expensive than their three piece counterparts are often crudely made and require more frequent service.

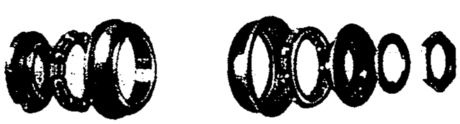


Fig. 9 -Exploded view of a bottom bracket for a one piece crankset.

There are two thread dimensions for the arm set and cones, 24 TPI (called USA standard), and 28 TPI (called Schwinn standard). There are also corresponding ball bearing retainer designations, #66 (USA standard, 10 5/16" ball bearings) and #64 (Schwinn standard, 9 5/16" ball bearings). In order to assure proper fit and adjustment, it's a good idea to replace the entire bottom bracket assembly all at once with the correct dimension to fit the arm set.

Three Piece Cranks

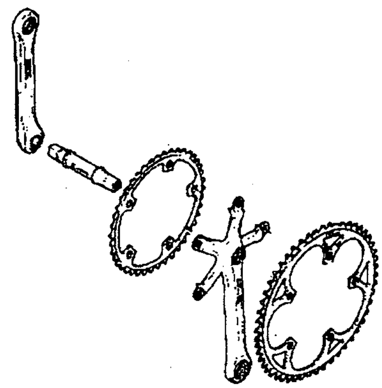


Fig. 10 - Three piece crank

Found on many multi-speed bicycles, including mountain bikes, road bikes, and a few high-end BMX bikes, the three-piece crank utilizes a left and right crank arm attached to a separate spindle. These cranks are most often made of aluminum alloy and are therefore considerably lighter than their one-piece counterparts. They are usually designed to accept 9/16" x 20 TPI pedals. There are actually three types of three-piece cranks used in the bicycle industry: cottered, square taper and splined. You may also encounter square taper and splined cranksets referred to as "cotterless."

Cottered Three Piece Cranks

This type of three piece crank uses a cotter to hold the crank arm onto the spindle. The cottered crank has been in use for over a century. By today's standards, however, the cottered crank is old technology and has been superceded by other designs. Cottered cranks are made of steel and are therefore very heavy. They are most often seen today on inexpensive bicycles built prior to the 1980's and on most stationary exercise bikes.

Fig. 11 - Cottered crank

The cotter, which holds the crank arm onto the spindle, is tapered. The cotter is pressed into a hole in the crank arm with the tapered side of the cotter facing a machined flat on the end of the spindle. As the cotter is pressed in, it wedges between the crank arm and spindle, holding the crank arm onto the spindle. Over a period of time, cotters tend to deform due to the torque on the cranks, causing the crank arms to loosen. The cotter must be replaced to correct this problem.

Cotters should be removed and replaced using a special cotter press, like the Park model #CR2. This tool is no longer manufactured, but is still commonly found in bike shop service departments. VAR still makes a cotter press. The press allows you to easily remove the old cotter and install a new one without damage to the bottom bracket bearing system. Avoid using a hammer for driving the old cotter out, because this can damage the bearings and races.

Square Taper and Splined Cranks

When the square taper crank was first introduced, this design was known as the "cotterless" crank to differentiate it from the older cottered three piece design. The splined crank was introduced several decades after the square taper, and uses a very different spindle design. However, what both designs have in common is that the crank arm is pressed onto the spindle with a fixing nut or bolt. These cranks may be made of steel, aluminum, titanium or carbon fiber, but aluminum is by far the most common. Crank arms are manufactured using one of several different methods - melt forging, cold forging, machining, welding, or with various carbon fiber construction processes. Melt forging is the most common method used. Molten aluminum is poured into a die, subjected to pressure and allowed to cool into its final shape.

Photo courtesy of FSA

Fig. 12 -Crank arms in various stages of the forging process

Higher quality cranks are frequently cold forged. This process is similar to melt forging, but the input material is solid, requiring more pressure to mold the crank into its final shape and refining the grain structure of the metal in the process. This process results in a uniformly strong crank arm. Other high-end crank arms are machined. This process takes a chunk of aluminum or "billet" and machines the shape of the crank arm out of the billet. This process is most often performed by CNC (Computer Numeric Controlled) machinery, which is operated through computer software. Carbon fiber is also a popular material for crank arms. Lastly, some crank arms are welded from tubular chromoly steel or titanium.

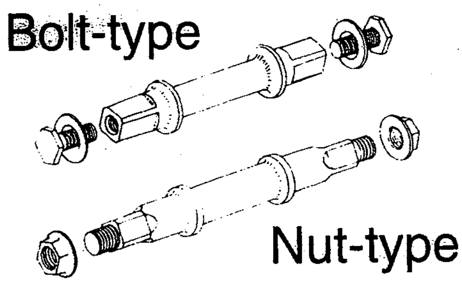
The right crank arm consists of a "spider" which the chainrings attach to via special chainring bolts. Spiders may consists of 3 to 5 arms with chainring mounting holes drilled through them that must match the mounting holes on the chainrings in order to be compatible. The imaginary circle that passes through the holes in the spider and chainring is called the "bolt circle diameter." There are many bolt circle diameters currently in use in the bicycle industry so there are also many chainrings that are only compatible with specific cranks. Chainring compatibility and bolt circle diameters will be discussed in more detail later in Chapter 4.

Some right crank arms actually consist of a separate spider and arm and the two pieces are swaged together. Other replaceable spiders are held on with a lock ring.

Crank arms come in varying lengths and are measured from the center of the spindle hole to the center of the pedal hole. Cranks are available in lengths ranging from 165mm to over 180mm and are usually sized on production bikes according to frame size - smaller bikes are equipped with shorter cranks, larger bikes with longer cranks.

Square Taper Spindle Design

Square taper spindles are now found mostly on older bikes and some lower priced newer bikes. The crank arm has a square opening in the center which is pressed over the matching tapered spindle end. The crank arm is tightened onto the tapered spindle using a bolt or nut threaded into or onto the spindle, depending on the design of the spindle (see figure 13).



Bolt-type spindles are generally superior to nut-type spindles in that they have the largest number of threads engaged in the spindle, assuring the crank will stay tight under heavy use. The number of threads on spindle bolts usually have three to four times more threads than the equivalent nut-type spindle. Because of this, the design of the nuts used on nut-type spindles have special serrations machined onto the back of the nut, designed to dig into the aluminum crank arm to help keep it tight. Nut-type spindles are found mostly on older bicycles and bolt type spindles on more current bicycles.

Splined Spindle Design

In an effort to lighten and stiffen bottom bracket spindles, this design uses a larger diameter, hollow spindle. There are currently four different standards in spline-style spindles. Two are used by Shimano, which are called Octalink V1 and Octalink V2 (figures 14 and 15). The third style, known as the International Spline Interface Standard (or ISIS, see figure 15), is being used by a number of manufacturers. The fourth style is called Power Spline. All four standards vary in spline depth and spline spacing, and in some cases spindle diameter, shape, and number of splines. Consequently, cranks and spindles are not interchangeable, even between the two Shimano standards. Shimano uses 8 splines, ISIS spindles have 10 splines, while BMX spindles come with 6, 8, 10 and even 48 splines.

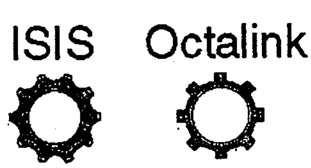


Fig. 14 -Profiles of two common spline standards

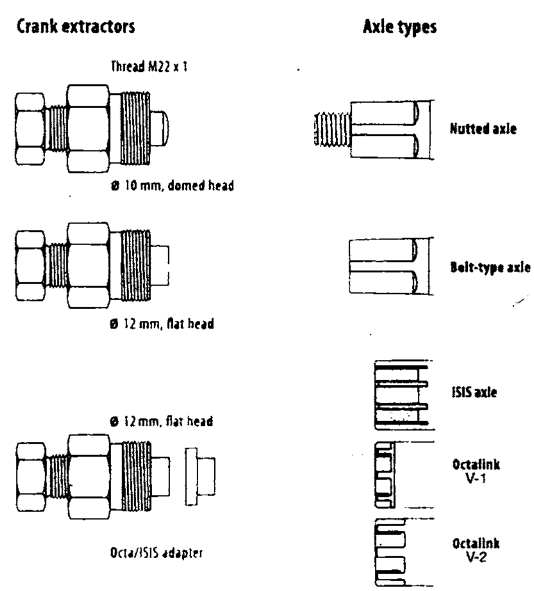


Fig. 15 - Crank extractor compatibility

Three Piece Crank Arm Removal

Two tools are required to remove crank arms: a crank bolt wrench (or thin-walled socket wrench) or an 8 or 10mm hex wrench and a crank extractor. The crank bolt wrench is a thin socket designed to fit into the small opening in the face of the crank, engaging the wrench flats of the square taper spindle bolt or nut. Crank bolt wrenches usually come with two socket sizes to fit the two typical sizes found on most square taper spindle bolts or nuts - 14mm and 15mm.

Removal of spline-style cranks can be accomplished with a standard square taper crank removal tool, but an adapter, available from both Park Tool and Shimano, may be necessary. Some cranks come with self extracting crank bolts which can be used in place of a crank removal tool.

Crank extractors are designed to remove the crank arm from the spindle. The extractor is made up of two pieces - an outer extractor body and inner plunger. The outer body threads into the dust cap threads of the crank arm while the inner plunger threads into the extractor body, making contact with the end of the spindle. Threading the plunger inward pushes the crank arm off the end of the spindle. Many (but not all) crank extractors are compatible with both the bolt and nut-type spindle. However, use of a nut-type only extractor on a bolt-type spindle can cause damage to the spindle. These extractors have a smaller diameter plunger which will enter the bolt hole and damage the first few threads as the crank is being extracted. Those only intended for bolt-type spindles have a flat plunger end should not be used on nut-type spindles, because the plunger will not thread out of the way when installing the tool.

STUDENT HANDS-ON:

Square Taper Crank Arm Removal

Tools needed:
Crank extractor
Adjustable wrench
8mm hex wrench, OR
Crank removal wrench, OR
14mm thin wall socket, OR
15mm thin wall socket
Ratchet wrench

Step 1 - Remove the dust caps, if present.

Step 2 - Remove the crank bolts or nuts using the appropriate tool. If it is a bolt-type spindle, remove the washer, which resides under the bolt. Some bolts have the washer built onto it. Important: Failure to remove the washer could permanently damage the crank because the extractor plunger will hit the washer instead of the spindle, stripping the extractor threads on the crank arm!

Step 3 - Before removing crank arms inspect the crank's compatibility with the spindle. First, check how far the crank arm is seated onto the spindle taper. Inspect both ends of the spindle taper, from behind the spider and under the spindle bolt or nut. If either end is within 1 millimeter of bottoming out, the crank may not seat properly when reinstalled and will not remain tight during use. Second, check the chainline of the bicycle. Is the right crank too far outward or inward, causing a poor chainline? If so, a new spindle may be installed during reassembly of the bottom bracket to correct the problem (more on this issue in the Chapter 4 Appendix).

Step 4 - Using the appropriate crank extractor, back the plunger out of the outer body as far as possible.

Step 5 - Carefully thread the outer body of the extractor into the crank dust cap hole threads, insuring that every thread is engaged as far as possible. The extractor body should be snug. There is no need to torque it beyond that.

Step 6 - Verify the extractor outer body is threaded into the dust cap hole completely while making sure the plunger turns freely. Then, lightly thread the plunger into the crank arm finger tight until it rests up against the end of the spindle.

Step 7 - Using a large adjustable wrench on the plunger wrench flats, carefully thread the plunger into the crank in a clockwise direction, watching the dust cap hole for possible thread failure. Continue turning until the crank comes off.

Step 8 - Back the plunger all the way out and then unthread the extractor from the crank arm.

Step 9 - Remove other crank arm using the same procedures as above.

Threaded Bottom Bracket Standards

Threaded bottom bracket shells come in different widths and thread standards, and this raises compatibility issues. The chart below lists the different threaded bottom bracket standards.

Threaded Bottom Bracket Standards

Standard	Thread Size	Shell Width	Non-Drive	Drive
ISO	1.375" X 24 TPI	68, 73, 83, 100mm	right hand thread	left hand thread
English BSC	1.370" X 24 TPI	68mm	right hand thread	left hand thread
Italian	36mm X 24 TPI	70mm	right hand thread	right hand thread
French*	35mm X 1mm	68mm	right hand thread	right hand thread
Raleigh*	1-3/8" X 26 TPI	71, 76mm	right hand thread	left hand thread
Swiss*	35mm X 1mm	68mm	right hand thread	left hand thread
Chater Lea*	1.450" X 26TPI		right hand thread	left hand thread

*These sizes are obsolete but may be encountered when working on very old bicycles.

Bottom Brackets for Three Piece Cranks

As mentioned previously in this chapter, there are one piece, two piece and three piece cranks in use in modern bicycles. All types of cranks must use a bottom bracket designed for the style of crank.

There are several bearing system designs used in bottom brackets. The serviceable design uses independent cups and cones, with loose or retainer bearings. There are also bottom brackets that use sealed cartridge bearings. Those will be discussed later in this chapter. Serviceable bottom brackets use two cups, which are threaded into each side of the bottom bracket shell (figure 16).

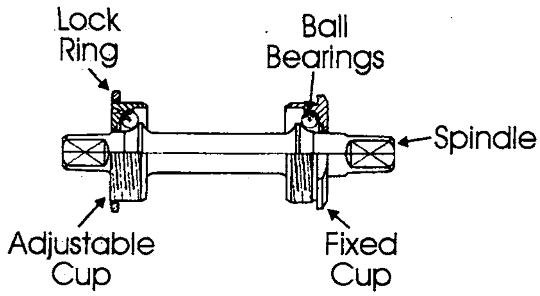


Fig. 16 - A cup and cone bottom bracket assembly for a three piece crankset

The right cup (on the drive side) is called the fixed cup, so named because it is threaded into the bottom bracket shell all the way until it stops in a fixed position - it is non-adjustable. The fixed cup has two wrench flats on the outside designed to accept a specially designed wrench. Most are 36mm from edge to edge. These wrenches are thin and have a tendency to slip off the flats. Stein has a Fixed Cup Tool that mounts over the wrench by threading into the bottom bracket spindle, preventing the wrench from slipping. There are also heavy duty type removers that grasp the fixed cup from both sides and provide increased leverage - particularly suitable for very tight fixed cups or for improved tightening against the face of the bottom bracket shell. VAR and Hozan both manufacture this type of remover. Thread direction of the fixed cup varies, depending on the standard used. English fixed cups (the most common) have left hand threads and Italian fixed cups have right hand threads.

The left cup (on the non-drive side) is called the adjustable cup. This is the side where bearing adjustment is made, by threading the adjustable cup inward or outward to get closer or farther from the bearings. Bearing adjustment is held in place by a lockring, which is threaded onto the outside of the adjustable cup and tightened against the face of the bottom bracket shell. Most adjustable cups have several evenly spaced pinholes machined into the face of the cup, designed to accept a pin spanner for adjustment, while others have slots or wrench flats. A lockring wrench is used to engage the notches in the lockring for loosening or tightening. All adjustable cups use right hand threads, regardless of national standards. For additional standards that have been used in the past few decades, consult Sutherland's Handbook, 6th Ed., page 3-2.

Some cups are equipped with some sort of rubber or plastic seal. The seal engages in the opening of the spindle hole and mates closely against the rotating spindle to help keep water and debris out of the bottom bracket bearings. The seal may be a simple o-ring or a more proprietary labyrinth system.

The cones in a serviceable bottom bracket bearing system are machined onto the spindle near the widest end of the taper. Spindles may be symmetrical or asymmetrical. Symmetrical spindles have equal distances from the cone to the spindle end on both sides and are found on all "low profile" designs where the crank is designed to be positioned closer to the frame. Older cranksets have asymmetrical spindles in which the right side is longer than the left side.

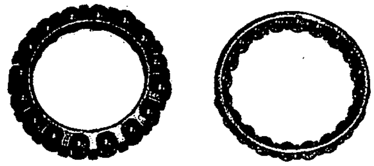


Fig. 17 - Bearings in a retainer

Japanese companies have established manufacturing criteria to conform to the Japanese Industrial Standard, known simply as JIS. JIS spindles are stamped with coding to help identify their specifications. Let's say, for example, a spindle is stamped D – 3NL. D indicates crank attachment method, 3 represents bottom bracket width, N indicates drive (right) side spindle width, and L indicates non-drive (left) spindle width. More identification and compatibility information can be found in Sutherlands 7th Ed., page 4-19 through 4-21, and Sutherlands 6th Ed. page 3-9 through 3-12.

Traditional cup-and-cone bottom brackets may contain either loose ball bearings or bearings held in place by a retainer (figure 17). Bearings held in place by a retainer are easier to install but quite often include fewer bearings because there are retainer "fingers" taking up some of the space that loose balls could be occupying. Loose ball bearings take longer to install, but provide the maximum bearing support possible for the ball tracks. If using retainers, it is important to properly identify the two distinct sides of the retainer so that the retainer is always installed in the proper orientation in the races.

The retainer has a solid ring from which the fingers that separate and contain the bearing radiate. The ball retainer can come in two configurations. It may have a small diameter ring around the inside circumference of the bearings. The correct orientation is this ring facing into the cup. If the retainer ring forms an outside circle around the bearings, it must face out of the cup. Note the difference between the bearings in figure 17.

STUDENT HANDS-ON:

Cup and Cone Bottom Bracket Disassembly

Tools needed:
Lockring wrench
Heavy duty fixed cup remover, OR
36mm fixed cup wrench and Stein fixed cup tool
Pin spanner

Step 1 - Before removal, slowly turn the bottom bracket spindle to evaluate for misalignment or improper bearing adjustment.

Step 2 - Inspect the depth of the adjustable cup relative to the outer edge of the lockring. It should be at least flush with the face of the lockring, or it can be protruding outward about 1 - 2mm. Protrusion of the bottom bracket cup by more than 2 mm may indicate an incompatible spindle type.

Step 3 - Remove the lockring using a lockring wrench or lockring pliers. Remove the adjustable cup using the appropriate spanner, being careful not to drop any of the ball bearings out of the cup. If the cup is very tight, consult an instructor.

Step 4 - Remove the spindle, noting the orientation of the label.

Step 5 - Remove the protective plastic sleeve, if installed. Remove the bearings from the fixed cup side.

Step 6 - Identify the thread standard used on the bottom bracket to determine which way to loosen the fixed cup (see page 3-18).

Step 7 - Remove the fixed cup using the appropriate tool.

Step 8 - Clean all parts and inspect for wear.

Inspection of Cup and Cone Bottom Bracket Parts

Once the parts have been cleaned, inspect both cups and the cones on the spindle for wear (figure 18). Look for:

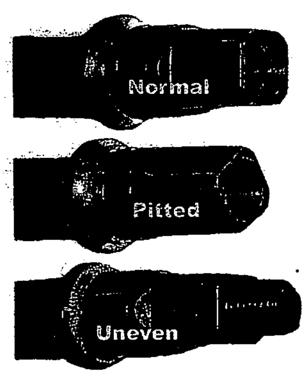


Fig. 18 - Normal and damaged ball tracks on cup and cone BB spindles

Pitting - Caused mostly by dirt and debris, or by over tightening, pitting is identified by rough spots and gouges in the ball track of the cups and cones. Very slight pitting can be felt by scratching a fingernail across the surface.

Uneven Ball Track - If the ball track on any of the parts does not run concentrically, there is some misalignment present in one or more of the parts. Look closely at each ball track. Does it run higher and/or lower on one or more races? If it does, closer inspection may determine the cause. Misaligned bottom brackets can be caused by several factors - most common, especially in mountain bikes, is a bent spindle. Roll the spindle across a flat surface, carefully viewing the ends to see if they move up and down as the spindle rolls. If bent, replacement of the spindle is necessary.

Another cause of misalignment is unparallel bottom bracket shell faces. This is caused by heat distortion from the welding or brazing process. If the faces are not parallel with each other, the cups have a tendency to distort to match the surface angles of the faces as they are tightened into place. The only solution to this problem is to properly machine the faces using a special bottom bracket mill (see Chapter 8). This is considered an advanced operation and is usually only performed on mid to high end bicycles, where perfect bearing alignment is essential to the smoothness and longevity of the components. Inexpensive components found on low to mid priced bicycles are generally made from softer materials, and therefore tend to wear-in with use. They can actually get smoother once they are broken-in by wearing themselves into concentricity, so milling of the faces on these frames is not necessary, nor is it cost-effective.

STUDENT HANDS-ON:

Cup and Cone Bottom Bracket Reassembly

Tools needed:

- Lock ring wrench
- Heavy duty fixed cup remover, OR
- 36mm fixed cup wrench and Stein fixed cup tool
- Pin spanner

Step 1 - Prepare the fixed cup for installation by applying Blue Loctite (#242), anti-seize or grease to the threads. If using Loctite, degrease the threads to prevent surface oil from impeding the curing of the Loctite. NOTE: In class this procedure will be done with grease!

Step 2 - Install the fixed cup using either a fixed cup wrench in combination with the Stein fixed cup spanner clamp, or one of the heavy duty removers such as the Var or Hozan. Tighten firmly.

Step 3 - Apply grease to the fixed cup bearing race through the adjustable cup side, or if using the Stein tool combination on the fixed cup, grease may be applied before installing fixed cup.

Step 4 - Install the bearings in the fixed cup. If using loose ball bearings, most bottom brackets use 11 1/4 inch bearings per side. If using ball bearings that are housed in a retainer, make sure to install the bearing retainers in the correct orientation.

Step 5 - Insert the spindle into the bottom bracket, seating it against the fixed cup bearings. Be certain the spindle is installed in its proper orientation. You should be able to read the label on the spindle from left to right from the rear of the bicycle.

Step 6 - Install the plastic protective sleeve, if supplied.

Step 7 - Prepare the adjustable cup by applying grease to the ball track and outside threads. Install the bearings into the cup using 11 1/4 inch bearings if loose, or if the bearings are housed in a retainer be sure to install the bearings in the correct orientation.

Step 8 - Install the adjustable cup so the cup is finger-tight against the bearings.

Step 9 - Apply grease to the lockring and install onto the adjustable cup finger tight. This is a good starting point for bearing adjustment.

Step 10 - Tighten the lockring using a lockring wrench or lockring pliers while holding the adjustable cup with the appropriate pin spanner. When tightening the lockring, be careful not to damage the surface of the shell.

Step 11 - Turn the spindle slowly to check for smoothness or roughness. Rock the ends of the spindle with both hands to detect play.

Step 12 - If the adjustment is too tight, hold the adjustable cup still with the appropriate spanner, loosen the lockring, loosen the adjustable cup slightly, and tighten the lockring while holding the adjustable cup in position. Recheck and repeat as necessary.

If the adjustment is too loose, hold the adjustable cup still with the appropriate pin spanner, loosen the lockring, tighten the adjustable cup slightly using the angle of the pin spanner as a reference, and tighten the lockring while holding the adjustable cup in position. Recheck and repeat as necessary.

STUDENT HANDS-ON:

Square Taper Crank Arm Installation

Tools needed:

- Beam-type torque wrench
- 8mm hex wrench
- Crank bolt wrench
- 14mm thin wall socket, OR
- 15mm thin wall socket
- Socket ratchet

Step 1 - Clean the bottom bracket spindle flats and inside of spindle hole with a clean rag. Clean inside of square tapered hole on the crank arm and inspect for damage or wear.

Step 2 - Check the right crank arm on the spindle in all four possible positions to check for the truest running position. Sight down over the front derailleur cage for alignment.

Step 3 - Grease the threads on the spindle bolt or nut. If a washer is being used with the bolt type, grease both sides of the washer.

Step 4 - Install the right side spindle bolt or nut to the manufacturer's recommended torque range using a torque wrench. If aluminum bolts are used, install first using a steel bolt to proper torque range, then remove and install the aluminum bolt in its place. Remember to grease the aluminum bolt first. If titanium bolts are used, apply anti-seize compound to the threads first.

Step 5 - With the increased leverage of the installed right crank arm, check the bottom bracket adjustment again by flexing the crank arm from side to side, checking for any looseness that was not apparent with your first adjustment. Readjust as necessary.

Step 6 - Install the left crank arm and tighten to manufacturer's torque specification.

Step 7 - When you have successfully reinstalled the bottom bracket and crank arms and are ready for a final check, have an instructor check your bicycle. If it passes the inspection, the instructor will sign it off on your Student Daily Checklist. After it is signed off, you may put it away.

Cartridge Bottom Brackets

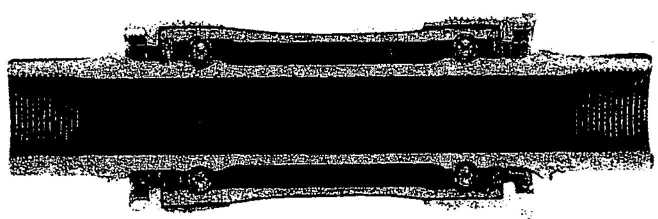


Photo courtesy of FSA

Fig. 19 - Cross section of a cartridge bottom bracket

There are two terms used to describe sealed bottom brackets - sealed cartridge unit bottom brackets and sealed cartridge bearing bottom brackets. These two terms are most often used interchangeably, but they are actually referring to two different types of systems.

A sealed cartridge unit bottom bracket is a system which has both cups attached to each other by way of a sleeve connecting the two sides in perfect alignment. Sealed cartridge units may use either ball bearings or cartridge bearings. Some systems are designed without a fixed cup side making the entire unit adjustable for chainline. The adjustment is held in place by a lockring on both sides. Simply by threading the entire unit from side to side one can achieve a more perfect chainline without the need for replacing the spindle.

Phil Wood pioneered the one-piece cartridge unit bottom bracket, and still manufactures them. These units are held in the bottom bracket shell by means of two rings that thread into each side of the shell, and this system provides some degree of chainline adjustability. They require a proprietary splined tool for installation.

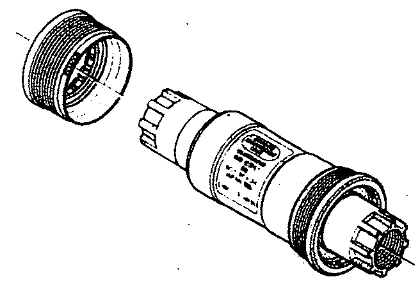


Fig. 20 - Shimano Octalink cartridge bottom bracket

In 1992, Shimano introduced the UN series of sealed cartridge unit bottom brackets. These units have a fixed cup side with a flange, so the entire unit threads into the shell from that direction. The other side is held in place by an "adapter" which threads up against the other end of the unit until tight. The Shimano sealed cartridge units are non-adjustable for chainline, other than replacing with another unit equipped with a longer spindle. They are also meant to be non-adjustable for bearing play, though the lower priced models are equipped with wrench flats designed to accept a special tool made by Park which allows bearing adjustment and overhaul.

Many other manufacturers, such as Campagnolo, Race Face, FSA, and Tange, make similar sealed cartridge unit bottom brackets.

STUDENT HANDS-ON:

Cartridge Bottom Bracket, Splined Crank Arm and Pedal Removal

Tools needed:

- VAR or Park cartridge BB tool
- 5mm, 6mm, 8mm and/or 10mm hex wrench
- Crank extractor
- Adjustable wrench
- Shimano adapter tool (#TLFC15)
- Pedal wrench

Step 1–Select an appropriate bike with a sealed cartridge unit bottom bracket.

Step 2 - Each bench partner should remove one pedal, using an appropriate pedal wrench. **Remember the left pedal is left-hand threaded!**

Pedals - Back off BB opposite

Use a quick release to take off to BB to hold tool

Step 3 - Inspect the pedals for wear by slowly turning the spindle. Check for looseness or tightness, for misaligned bearings, and for any other problems that may be apparent. Leave the pedals off the bicycle.

Step 4 – Remove the dust cap, if applicable, then remove the crank arm fixing bolt. Inspect and remove the crankbolt washer. Before using the crank extractor, install the special Shimano adapter tool (#TLFC15) into the bottom bracket spindle, then extract the crank in the usual manner. There are other crank extractors specifically designed for use with billet spindle bottom brackets and do not require the use of the special Shimano tool.

Step 5 – Remove the bottom bracket adapter cup from the non-drive side of the frame using a splined cartridge bottom bracket tool. Back out the mounting screw for the under-bottom-bracket cable guide, if applicable.

Step 6 – Remove the cartridge unit from the drive side of the frame using the same tool.

Step 7 - Inspect and clean the bottom bracket. Measure the spindle width and shell width, and note the model of bottom bracket. Write the information below:

73	113	BB-ES51	Octolink V2
Shell Width	Spindle Length	Bottom Bracket Model	Spline Standard

STUDENT HANDS-ON:

Cartridge Bottom Bracket, Crank Arm & Pedal Reinstallation

Step 1 – Grease the threads of the cartridge unit bottom bracket and install it into the drive side of the bottom bracket shell. Tighten to manufacturer's torque specification.

Step 2 – Grease the adapter threads (unless the adapter is plastic)and install into the non-drive side of the bottom bracket shell. Tighten the adapter to manufacturer's torque specification.

Step 3 – Apply a small amount of grease to the splines on both ends of the spindle.

If installing a one-key release style crank, remove the dust caps to visually verify the splines align properly. Tighten each crank bolt to the manufacturer's torque specification. Reinstall the dust caps, if applicable.

Step 4 - Grease the threads on both pedals and install. Tighten the pedals to the manufacturer's torque specification.

Step 5 - When you have successfully reinstalled the bottom bracket, crank arms, and pedals, and are ready for a final check, have an instructor check your bicycle. If it passes the inspection, the instructor will sign it off on your Student Daily Checklist. After it is signed off, you may put it away.

TWO PIECE CRANKS

The two piece design integrates the bottom bracket spindle with one crank arm. Bullseye, a small California manufacturer, is credited with developing the two-piece design in the 1980's. Shimano first released two-piece cranks with its 2003 XTR mountain group and 2004 Dura Ace road group. Other manufacturers, such as Race Face, FSA, Campagnolo, SRAM, TruVativ and MRP, manufacture similar cranks.

In two piece systems, the bearings are housed in special cups that thread onto the bottom bracket shell, actually placing the bearings outboard of the shell. The method of attaching the crank arms to the spindle varies, depending on manufacturer.

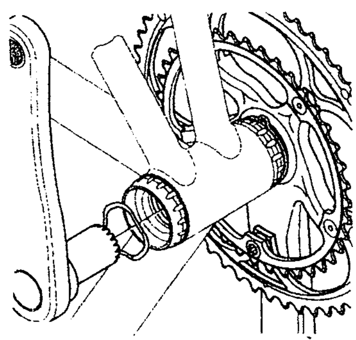
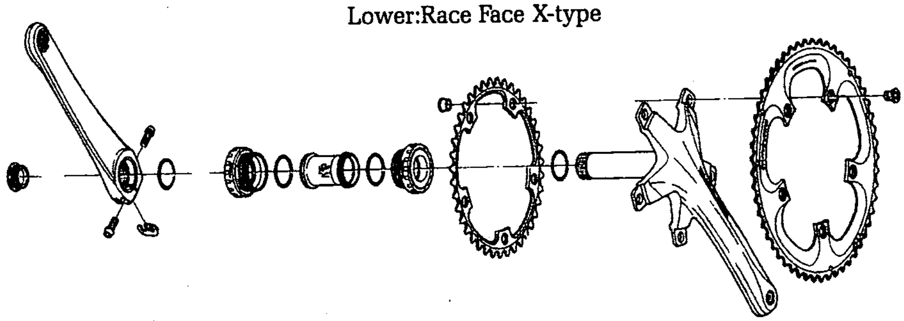
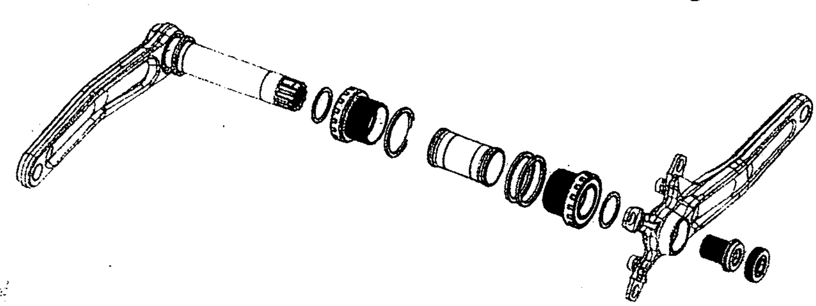


Fig. 21 - Different two piece crank designs.
Upper: Campagnolo Ultra Torque.
Middle: Shimano Hollowtech II.
Lower:Race Face X-type





STUDENT HANDS-ON:

Shimano Hollowtech II 2 Piece Crank and Bottom Bracket Removal

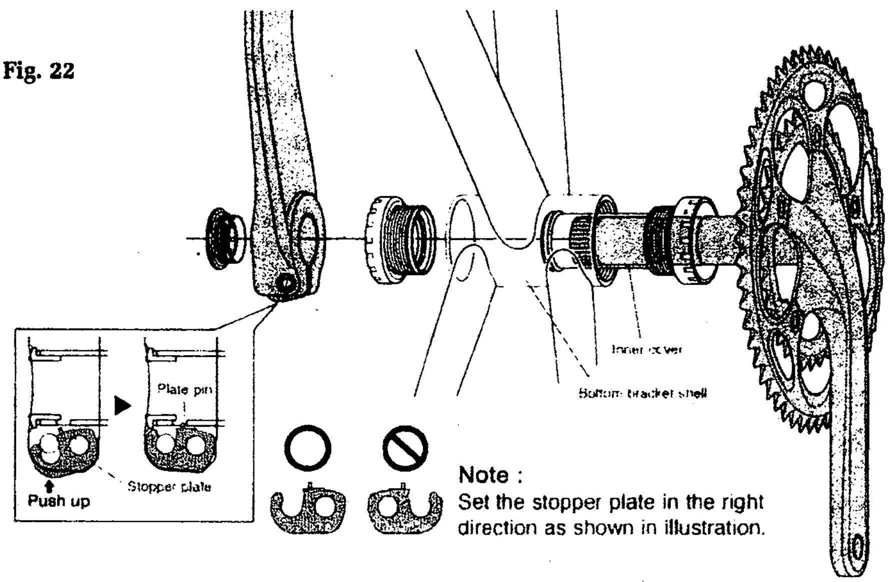
Tools needed:
Park BBT19
Shimano TL-FC16 tool
5mm and 6mm allen wrenches
Rubber mallet
Torque wrench

Step 1 – Remove the pedals if necessary

Step 2 – Loosen the two pinch bolts on the non-drive crank arm equally and incrementally using a 5mm hex.

Step 3 – Remove the bearing preload cap using the appropriate tool (Shimano tool TL-FC16).

Fig. 22



Step 4 – The non-drive crank arm may incorporate a stopper plate mounted to the pinch bolts. This stopper plate has a pin which drops into a corresponding hole in the spindle and prevents the crank arm from falling off in the event of a pinch bolt failure. Before attempting to remove the non-drive crank arm this stopper plate must be rotated upwards with a scribe or flat-bladed screwdriver.

Step 5 – Remove the non-drive crank arm from the spindle by pulling firmly. If the crankset has three chainrings there will be a black, tapered spacer behind the crank arm. Note its orientation.

Step 6 – Remove the drive-side crank arm and spindle assembly from the bottom bracket by pulling firmly.

Step 7 – Remove the non-drive bearing cup using the appropriate tool (Park Tool BBT19). This is always a right-hand thread.

Step 8 – Remove the drive-side bearing cup using the appropriate tool (Park Tool BBT19). This is left-hand thread for English/ISO threaded bottom brackets and right-hand thread for Italian threaded bottom brackets. Measure the width of the BB shell prior to removal if you are unsure. The inner cover should be removed with one of the cups.

STUDENT HANDS-ON:

Shimano Hollowtech II 2 Piece Crank and Bottom Bracket Installation

Step 1 – Inspect the threads and faces of the bottom bracket shell. If corrosion or damage is present it may be necessary to chase the threads and/or mill the faces of the shell (see Chapter 8 of this manual for instructions).

Step 2 – Snap the inner cover into the drive-side bottom bracket cup. If cup spacers are required to adapt the bottom bracket to the frame place them on the threaded portion of the drive-side cup. Thread the cup into the drive side of the bottom bracket shell using the appropriate tool (Park Tool BBT19). This is left-hand thread for English/ISO threaded bottom brackets and right-hand thread for Italian threaded bottom brackets. Torque to manufacturer's specifications.

Step 3 – Place any spacers requited to adapt the bottom bracket to the frame and place them on the non-drive cup. Thread the cup into the non-drive side of the bottom bracket shell using the appropriate tool and torque to manufacturer's specifications.

Step 4 – Apply a thin layer of grease to the spindle. Install the drive-side crank and spindle assembly through the bottom bracket.

Step 5 – Apply a thin layer of grease to the splines on the spindle. If the crankset has three chainrings, install the black, tapered spacer on to the spindle (tapered face out), followed by the non-drive crankarm.

Step 6 – Grease the threads of the bearing adjustment cap and thread into the spindle using the appropriate tool (TL-FC16). Tighten only enough to eliminate any lateral play and allow the pin on the stopper plate to drop into the corresponding hole in the spindle. Check for lateral play by first pushing the crankset inboard and then pulling it outboard. Any dimensional change in the gap between the non-drive crankarm and the bottom bracket cup is indicative of a loose bearing adjustment cap. Tighten and re-check for play.

Step 7 – Ensure that the stopper plate is down. Tighten the pinch bolts equally and incrementally to the manufacturer's torque specifications.

Step 8 – Re-install pedals and torque to manufacturer's specifications.

Threadless Bottom Bracket Standards

Early Klein, Fisher, Fat City, and Merlin bicycles used a system in which cartridge bearings were pressed directly into a larger diameter threadless shell. While this system lost favor in the marketplace for a decade or so, three newer versions are now available. All of these systems use a larger diameter bottom bracket shell. This allows frame manufacturers to increase the diameter of tubes that are joined to the BB shell, which in turn increases frame stiffness.

The first is called BB-30. It was developed by Cannondale, but is being supported by a number of different frame and component manufacturers. The BB-30 system uses a traditional width bottom bracket shell (68mm for road and 73mm for mountain) that does not have any threads. The bearings are placed directly into the bottom bracket shell and are held in place by a snap ring. The crank used with this system has a 30mm diameter bottom bracket spindle. There are adapters available for BB-30 to allow the use of a standard threaded bottom bracket.

The second system is BB-86/92. It was developed by Shimano and has been adopted by a number of frame manufacturers. This system uses a bottom bracket shell that is wider than a traditional shell (86mm for road and 92mm for mountain) and does not require a threaded bottom bracket shell. The bottom bracket bearings are housed in cups that are pressed into the frame. This system utilizes a 24mm diameter bottom bracket spindle. It is only compatible with BB-86/92 bearings, and no adapter kits

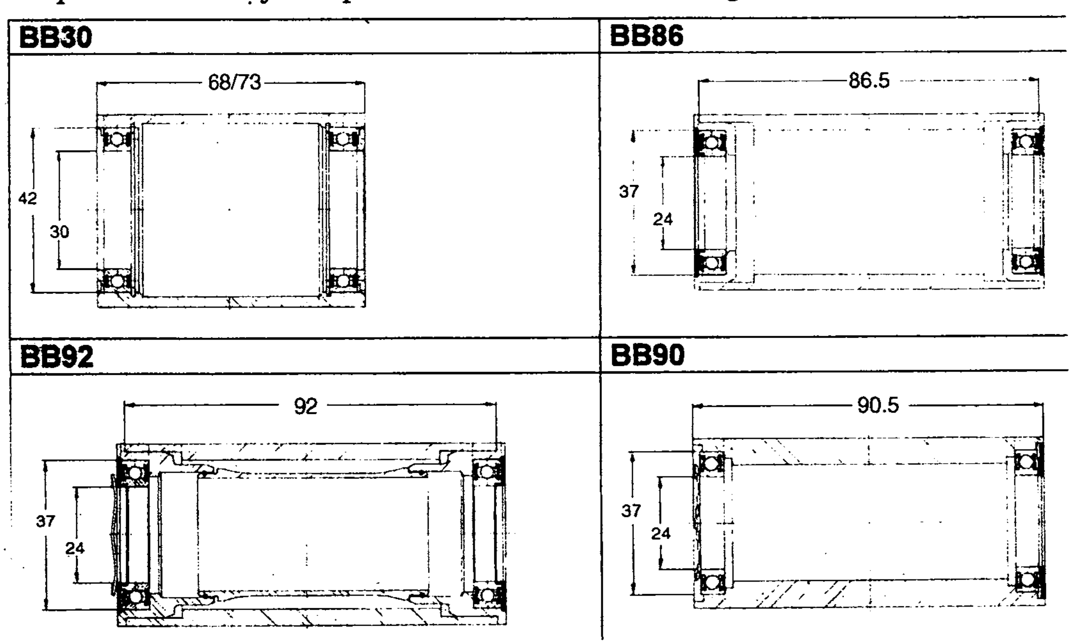


Chart courtesy of FSA

are available for use with a standard threaded bottom bracket.

The third system was developed by Trek, and is called BB-90. This design is similar to the BB-86/92, in that it is compatible with a 24mm bottom bracket spindle. The main difference is that the BB-90 bearings are pressed directly into the frame without the use of a bearing cup.

For ease of comparison, the various threadless bottom bracket standards are listed below.

Press-Fit Bottom Bracket Comparison

Type/Name	Shell Width	Shell ID	Snap ring groove in shell?	Bearing or Cup?	Bearing ID	Seen on
BB30	68 or 73 mm	42 mm	yes	bearing	30 mm	various
PF30	68 or 73 mm	46 mm	no	cup	30 mm	various
BB86/92	86.5 or 91.5 mm	41 mm	no	cup	24 mm	various
BB90/95	90.5 or 95.5 mm	37 mm	no	bearing	24 mm	Trek
BBright Direct Fit	79 mm	42 mm	yes	bearing	30 mm	Cervelo
Bbright Press Fit	79 mm	46 mm	no	cup	30 mm	Cervelo
BB386EVO	86.5 mm	46 mm	no	cup	30 mm	Various

STUDENT HANDS-ON:

BB30 Bearing Removal

Tools needed:

- FSA BB30 bearing removal tool (#EE019)
- Punch
- Small hammer
- Snap ring pliers
- Safety glasses

Step 1- Tilt the bearing removal tool inward so that it rests against the inner face of the bearing without contacting the snap ring.

Step 2 - Place the punch in the machined recess of the bearing removal tool from the inside of the BB shell. Using a small hammer, lightly tap the punch until the bearing is removed from the shell.

Step 3 - Repeat the same procedure for the second bearing.

Step 4- Remove the snap ring using the snap ring pliers. Engage the pliers into the two holes in the snap ring and collapse the snap ring so that it can be removed from the machined groove and bottom bracket shell. This step is unnecessary if only the bearings are being replaced.

STUDENT HANDS-ON:

BB30 Bearing Installation

Tools needed:
FSA BB30 bearing press kit (#EE041)
Park headset press
Snap ring pliers
Deburring tool
Safety glasses

Step 1 - Check the condition of the bottom bracket shell and remove any burrs with a deburring tool. Apply a thin layer of grease to both the bottom bracket shell and snap ring groove.

Step 2 - Using snap ring pliers to collapse the snap ring, insert the collapsed snap ring into the machined groove in the bottom bracket shell. Ensure that the snap ring is completely seated in the groove by pushing against it with a plastic tire lever. Repeat for the opposite side.

Step 3 - Separate the base plate from the main shaft of the headset press. Install one Park stepped cone onto the main shaft of the headset press with the large end toward the handles. Then install one of the small bearing press adapters (2 included in kit) onto the main shaft of the headset press with the smaller diameter facing away from the handle. Slide a bearing onto the main shaft until it meets squarely with the bearing press adapter.

Step 4 - Carefully pass the main shaft of the headset press through the bottom bracket. Install the large bearing press adapter followed by the Park stepped cone (with the small diameter towards the BB shell). Finally, install the base plate from the headset press with the widest portion contacting the Park stepped cone.

Step 5 - Support the bearing press from both sides of the bottom bracket shell and begin to advance the threaded handle on the press, making sure that the bearing that is being pressed is starting as square as possible.

Step 6 - Continue advancing the threaded handle until the 1st bearing is completely seated against the snap ring.

Step 7 - Remove only the base plate, Park stepped cone and large adapter from the headset press. Slide the second bearing onto the main shaft of the press followed by the smaller adapter so that it interfaces with the inside diameter (ID) of the bearing. Install the Park stepped cone (with small diameter towards the BB shell) and base plate with the large diameter end facing toward the frame.

Step 8 - Advance the threaded handle, making sure the bearing is seating squarely. Continue to advance the threaded handle until the bearing is seated completely against the snap ring. Ensure the final bearing depth is equal around the circumference of the shell.

Step 9 - Install the bearing shields with the machined groove facing inward toward the bearing.

Step 10 - When you have successfully reinstalled the bottom bracket, and are ready for a final check, have an instructor check your work. If it passes the inspection, the instructor will sign it off on your Student Daily Checklist. After it is signed off, you may put it away.

Additional Reading about Used Wheel Repair, Tires and Tubes, Repair Stands, Pedals, Bottom Brackets and Cranks

The purpose of this list is to provide some alternate sources to help you learn the material covered in class. There is no requirement to do any of this reading. Read as little, or as much as you would like.

Sutherland's Handbook for Bicycle Mechanics (6th Ed):

Tires, Pages 12-1 through 12-6

Pedals, Page 1-1

Bottom Brackets, Pages 3-1 through 3-58

Sutherland's Handbook for Bicycle Mechanics (7th Ed):

Tires, Pages 10 -1 through 10-22

Pedals, Cleats and Shoes, Pages 2 -1 through 2-16

Bottom Brackets, Pages 4-1 through 4-30

Web Resources:

Sheldon Brown: Tire Sizing

www.sheldonbrown.com/tire_sizing.html

Bicycle Pedal History Museum

http://www.speedplay.com/index.cfm?fuseaction=pedalmuseum.intro

Chapter 3 Appendix

Pedal Service

Pedal Bearing Adjustment - Many pedals are designed with a simple cup- and-cone bearing system. They can be identified once the dust cap is removed and the parts exposed. These systems utilize a locknut against a keyed-washer, sitting against a cone. Adjusting these pedals is no different than a traditional hub adjustment, except you cannot attach a cone wrench to the cone to hold it still. The cone is recessed inside the pedal, making it impossible to do so. For that reason, a keyed washer is always used in these types of pedals to act as a buffer between the tightening locknut and cone. In lieu of a cone wrench, simply place a small flat-blade screwdriver against the wrench flats of the cone to make your adjustment, and then tighten the lock nut. The keyed washer will keep the locknut from altering the cone adjustment.

A properly adjusted pedal should rotate freely with no discernible play. If looseness and binding are felt as you turn the spindle, it is an indication of a misaligned bearing system, most often caused by a bent spindle. Replacement of the spindle is the only solution and many pedal manufacturers do not offer replacement parts, so quite often the entire pedal must be replaced. Pedals are most often sold in pairs only, so it may mean a replacement of both pedals.

Pedal Overhaul - There are two axle designs used in pedal bearing systems - the traditional design with an outboard adjustable cone and locknut assembly (used in quill pedals, many clipless pedals, and mountain bike pedals), and the one-piece design (used in SPD style pedals and most platform pedals). The overhaul procedure is identical for both - clean races, replace bearings, repack grease, adjust and tighten, etc. - except the extraction of the parts differ.

Traditional Spindle Design - The traditional pedal spindle is very much like a hub axle, except the inboard cone is machined onto the spindle. The outboard cone and locknut are threaded onto the end of the spindle, with the keyed washer in between. These spindles are extracted by removing the dust cap on the outboard side, removing the locknut, keyed washer, and cone, then pulling the spindle out from the inboard (crank) side. Reassembly is the reverse procedure.

One Piece Spindle Design - The one-piece design features a spindle/bearing unit, which is installed and extracted from the inboard side only. These pedals require a special tool designed for each particular type of pedal, usually splined, which fits over similar splines found on the inboard pedal side. The spindle is then extracted by unscrewing the entire spindle and bearing assembly out of the pedal body. Once the bearing is extracted, the spindle assembly can be overhauled as a complete unit, or the entire spindle assembly can be replaced. When extracting the spindle from the pedal body, please note the extraction thread direction as inscribed on the spindle near the extraction splines. Right pedals use a left hand thread for the spindle/body extraction threads and left pedals use a right hand thread. The thread direction is the exact opposite of the threaded post which screws into the crank arm.

How-To: One Piece Crank Bottom Bracket Overhaul

Step 1 - Remove the left pedal. It is not necessary to remove the right pedal to perform a one piece bottom bracket overhaul.

Step 2 – Loosen the rear axle nuts and slacken the chain enough to remove the chain from the chainring. If it is a coaster brake hub, you may need to loosen the brake arm mounting bolt in order to slide the wheel forward in the dropouts. You can also remove the chain altogether if you think it might get in the way.

Step 3 – Loosen and remove the bottom bracket locknut by turning it clockwise (it is a left hand thread). Remove the keyed washer and unthread the adjustable cone, removing it by sliding it over the crank arm.

Step 4 – Remove the left bearing retainer from the cup. Remove the crank by feeding it through the bottom bracket shell from left to right. It may help to keep the right bearing retainer compressed against the right side fixed cone as the crank is fed through the frame.

Step 5 – If removing the chainring/spider or replacing the right side fixed cone, place the right side of the crank in a soft jaw vice with the fixed cone facing up. Using the appropriate tool, remove the fixed cone by turning it counter clockwise (it is a right hand thread). Note the orientation of the chainring(s) before lifting off of the crank to assure proper reinstallation.

Step 6 – Clean and inspect the bearing surfaces for wear or cracking. If the cups are being replaced, carefully drive them out of the frame with a punch and hammer, ensuring they are driven out squarely. Press in new cups using a bottom bracket cup press or a headset cup press

Step 7 – Install the chainring/spider on the crank the same way it came off. Make sure the hole on the chainring spider lines up with the peg on the crank arm. Grease the fixed cone threads and install the fixed cone onto the crank. Tighten the fixed cone to a minimum of 25 ft. lbs. (300 in. lbs.).

Step 8 – Apply a layer of grease to the ball track of the fixed cone. Feed a well-greased bearing retainer over the left crank arm and onto the right fixed cone, making sure the retainer fingers will be facing the cup and the open bearing surfaces are against the cone.

Step 9 – Thread the crank back through the bottom bracket shell from the right side of the frame. Apply a thick layer of grease to the left cup and install a well greased bearing retainer, again making sure the retainer fingers will be facing the cup and the open bearing surfaces are against the cone.

Step 10 – Remembering that the left side of the crank has left hand threads, install the adjustable cone and tighten it finger tight. Back the adjustable cone off 1/8 to 1/4 turn to compensate for the compressive forces exerted by the locknut. Install the keyed washer and locknut. Tighten the locknut to 240 – 300 in. lbs. As in adjusting most bearing assemblies, one piece bottom brackets should feel "as free as possible with no play."

Step 11 – Reinstall the pedal(s) and chain. Set the chain tension and secure the axle nuts. If the rear hub is a coaster brake, make sure the brake arm mounting bolt is tight.

How-To: Cotter Removal and Replacement

Step 1 - Remove the nut and washer from the old cotter. Using a cotter press, align the extractor with the threaded post of the cotter. Turn the press handle clockwise until the old cotter has been pressed completely out.

Step 2 - Examine the old cotter carefully. There are two areas of compatibility which must be addressed in order to get an exact replacement - diameter and taper. Measure the diameter with calipers in millimeters, or use the Park Spoke Ruler for determining cotter diameter. Cotters come in 8mm, 8.5mm, 9mm and 9.5mm diameters, and the replacement diameter must match the old cotter's diameter.

Step 3 - Examine the taper of the old cotter. The new cotter must match the taper of the old cotter in order to be pressed into the crank arm to the same depth as before. If the taper is too steep, the cotter cannot be pressed in far enough and there may not be enough threads protruding for the washer and nut to attach to. If the taper is too shallow, the cotter may press in too far, making it impossible to tighten the crank adequately to the spindle.

Step 4 - Once a replacement cotter has been found, align the crank arm onto the spindle by insuring the hole in the crank arm is in line with the spindle cutout. Insert the new cotter with the taper side against the spindle flat. Using the cotter press, install the new cotter onto the spindle until it is fully seated.

Step 5 - Install the washer and nut, using a small drop of light thread locking compound on the threads. Do not overtighten the nut, it can strip the threads. Never attempt to draw the cotter into the crank by tightening the nut; use a cotter press!

Step 6 - When replacing cotters on both sides, they must be inserted into the crank arm from opposing directions for the two cranks to line up correctly.

Chapter 4

Chainrings, Chains, Freehubs, Freewheels, Cassettes, Gearing

Objectives:

- Understand chainring compatibility
- Identify, service and replace chains
- Identify and replace freewheels and cassettes
- Replace freehub mechanisms
- Service cartridge bearing hubs

CHAINRINGS

Chainrings can be constructed of steel, aluminum, titanium or carbon fiber, sometimes in combination. Steel chainrings are usually found on inexpensive bicycles, but even on high-end triple cranksets, the inner chainring is most often steel, as it is more wear- resistant than aluminum.

Larger chainrings, such as the middle and outer rings on triple cranksets or both rings on a double, are often made of aluminum. Although aluminum is lightweight and somewhat soft, large aluminum rings do not experience excessive wear. This is due to the distribution of pedaling force over a larger number of chainring teeth engaged on the chain. In fact, aluminum chainrings tend to wear at about the same rate as the rear cogs of freewheels and cassettes, even though the rear cogs are usually made of steel.

Titanium and carbon fiber chainrings are relatively rare, but do see use in applications like time trials where light weight is a key factor. Also, chainrings are being manufactured that use carbon fiber sections, but with the teeth made of steel, titanium or aluminum alloy. Chainrings must be drilled with the appropriate number and spacing of mounting holes to match the crank's drilling. Most chainrings designed for the two larger positions of the spider use a 10mm diameter hole, while inner chainrings designed for triple cranksets use an 8mm diameter hole. Chainrings often have countersinks for the chainring bolt or nut head to rest in. The countersink is only used on one side of the chainring, so that the non-countersunk side can mount flush against the crank arm spider.

Nearly all of today's chainrings have specially designed teeth to improve shifting. Many use special ramps, pins or hooks that have been machined or riveted onto the face of the chainring. These features assist the derailleur during shifting, lifting the chain from one chainring to the next. Each chainring is designed to work in conjunction with adjacent chainrings of the same design. Mixing them with other designs or odd sizes can hamper shifting performance.

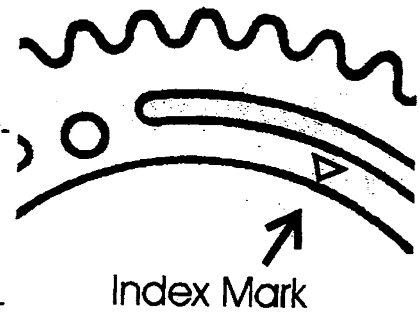


Fig. 1 - Look for an index mark to help with chainring orientation.

The orientation of these chainrings is equally important — all of the aforementioned shifting features must line up with each other. To ensure correct orientation, most chainrings have a small index mark (see figure 1).

Chainring Spacing

The spacing between chainrings is determined by the thickness of the spider arm and is engineered into the crankset, although some cranksets also use small spacers between the chainrings. Chainrings vary in thickness, so when replacing an original chainring with one from a different manufacturer, especially one of a differing material, the mechanic must assure that the spacing remains the same. The spacing must be narrow enough to keep the chain from jamming in between the chainrings, yet wide enough to prevent the chain from rubbing adjacent chainrings or overshooting the chainring while shifting.

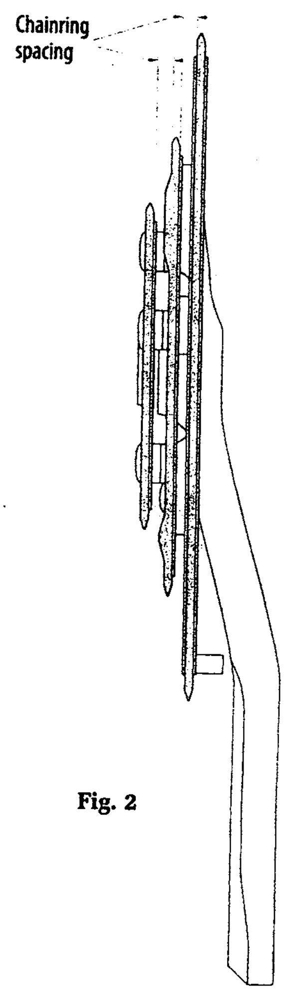


Fig. 2

Bolt Circle Diameter

Chainring mounting holes are drilled in a pattern designed to fit a specific crank arm spider. The diameter of the circle which passes through the center of all the mounting holes is called the "bolt circle diameter" or BCD (see figure 3). This measurement is used to determine the compatibility of chainrings and cranks – quite simply, a chainring will not fit on a crank unless the two components' bolt circle diameters match. Road racing bicycles generally use larger diameter chainrings, so a larger BCD is necessary in order to place the chainring mounting bolts as close to the teeth as possible. This creates a stiffer, more efficient drive train.

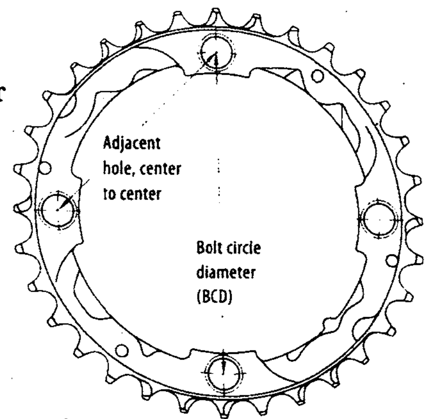


Fig. 3

Chainrings found on mountain, commuter, and touring bikes are generally smaller in diameter, thus the bolt circle diameters are proportionately smaller.

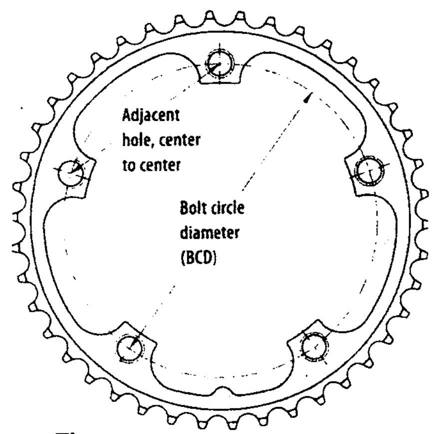


Fig. 4

When manufacturers design and specify dimensions for chainring compatibility, bolt circle diameter is one aspect that must be considered. Common bolt circle diameters are based on a 4 or 5 bolt pattern.

When measuring a 4 bolt pattern, simply measure across the diameter at the bolt circle (figure 3). The 5 bolt circle diameter is more difficult to measure because there are no mounting holes directly opposing (figure 4).

The most accurate way to determine the bolt circle diameter of a given chainring is by measuring the distance between two adjacent mounting holes, called the "hole center to hole center" measurement (see figure 4). This measurement is mathematically related to the bolt circle diameter. You can then consult a reference table to determine the true bolt circle diameter. Sutherland's Handbook 7th Ed., pages 3-16 through 3-19, includes a chainring sizer that allows you to place a chainring on a template to determine the bolt circle diameter.

Some Common Bolt Circle Diameter Measurements		
Crankset Style	**Bolt Circle Diameter**	**Hole Center to Center**
Road bike double (both chainrings)	130mm	76.4mm
Road bike triple (large and middle)	130mm	76.4mm
Road bike triple (inner)	74mm	43.5mm
Road bike double Campagnolo	135mm	79.4mm
Road bike triple Campagnolo (middle/outer)	135mm	79.4mm
Road compact (both chainrings)	110mm	64.7mm
Track	144mm	84.6mm
MTB 3x9 or 3x10 (middle/outer)	104mm	NA
MTB 3x9 or 3x10 (inner)	64mm	NA
SRAM 2x10 (outer)	120mm	NA
SRAM 2x10 (inner)	80mm	NA
Shimano 2x10 (both chainrings)	88mm	NA

Chainring Fasteners

Chainrings are held in place by special mounting bolts. Several types of bolts have been used over the past thirty years, but only two types are found on cranksets currently being manufactured.

One type is actually a bolt and nut assembly, sometimes supplied with a chainring spacer, and is designed to be used with chainrings attached to the bolt hole pattern located at the edges of the spider (the largest chainring positions). The bolt uses an 8 x .75 mm thread with either a 5 mm hex wrench or a Torx head which mounts through the outside of the largest chainring. The nut has an outside diameter of 10mm, designed to fit through the mounting holes of middle chainrings on triple cranksets and inner chainrings of double cranksets. The nut has a screwdriver slot on the back to accept a special chainring spanner wrench to keep the nut from turning while tightening the bolt. Some nuts use a hex hole instead of the screwdriver slot.

The other type of chainring bolt you will encounter is designed for use with the inner chainrings on triple cranksets. This bolt also uses an 8 x .75 mm thread, but without a nut. It bolts directly into the extra set of tapped holes located on the inside of the crank arm spider and also has a 5 mm hex wrench or a Torx head.

For additional information regarding chainring bolt design, consult Sutherland's Handbook, 6th Ed., page 2-8.

STUDENT HANDS-ON:

Chainring Removal

Tools needed:
Chainring pin spanner
Torx T30 wrench
Torque wrench

Step 1 - Note the orientation of the chainrings before disassembly. Before removing any bolts, check to see if there are any special spacers under any of the chainrings. If so, note the orientation of the spacers as you remove them.

Step 2 - On triple cranksets, remove the inner chainring.

Step 3 – Remove the outer chainrings.

Step 4- Clean and inspect the chainrings and crank arms for wear and/or damage.

Step 5 - Measure the hole center to hole center for each chainring. Use the Sutherland's Handbook, 7th Ed., pages 3-16 to 3-19 to determine the equivalent bolt circle diameter and range of teeth available for the bolt circle. Note your results below:

	Bolt Hole Center - Center	Bolt Circle Diameter	Range of Teeth
Inner	43.5mm	74mm	________
Middle	76.4mm	130mm	________
Outer	76.4mm	130mm	________

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STUDENT HANDS-ON:

Chainring Installation

Step 1- Apply grease or thread compound to all chainring bolts before reassembly.

Step 2 - Reinstall chainrings onto the spider. Note direction and position. On triple cranksets, install the outer two chainrings first.

Step 3 – Recheck chainring orientation. Tighten the mounting bolts to the manufacturer's torque specification.

Step 4 - Reinstall the crank arms (refer to 2 piece reassembly, Chapter 3)

Step 5 – Have an instructor check your work.

CHAINS

Chains can be differentiated by certain design aspects. For example, some chains have bushings, and some do not. A bushing is a metal sleeve that is inside the chain's rollers. The bushing serves to support the chain roller and pin and also limits how much the chain can flex. Previous to indexing derailleur systems, it was desirable to have a chain with very limited flex or twist. Index shifting systems, though, work better with a design that allows for more chain flex. As a result, most contemporary derailleur-equipped bicycles use a bushingless chain.

Second, the side plate design of chains differ. Some chains have flat side plates, whereas others have shaped or beveled side plates. Manufacturers of bicycle chains will often incorporate such features to enhance the shifting quality of the chain. Often such features are intended to work in unison with specific chainrings or cogs.

Chain part identification

1 Roller link plate (inner plate)
2 Pin link plate (outer plate)
3 Pin
4 Roller
5 Bushing

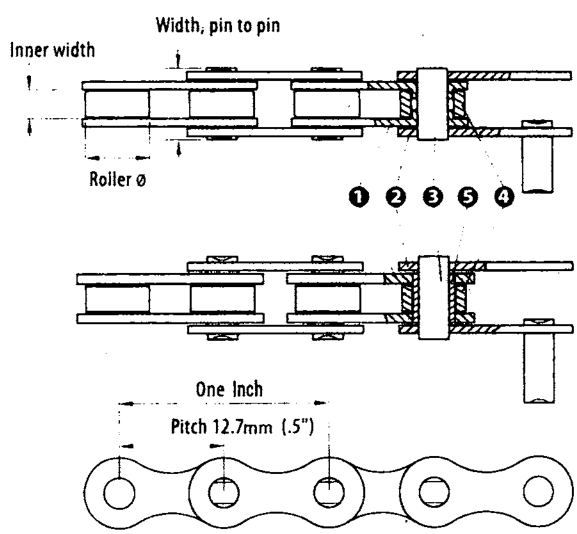

Fig. 5

The pins holding the links of the chain together are most often peened. Peening is an intentional deformation of the end of the chain pins. This process makes the ends of the pin wider, and therefore limits the ability of the chain's side plates to pull off the end of the pin. This is how most chains break. If the chain receives an excessive lateral load, the side plate can be forced off the end of the pin, thereby breaking the chain. When extracting a chain pin with a chain tool, the peening is sheared off, resulting in a potentially weak link. Therefore, a chain pin should never be re-used. In fact, it is recommended that the chain be removed from the bike as seldom as possible; but if it is removed, the chain should always be reassembled with new links or pins according to the manufacturer's specifications.

Traditionally, there have been two common designations of bicycle chains, 1/2" x 1/8" and 1/2" x 3/32". Their size is expressed by first describing their "pitch", which is the distance between the center of one pin to the center of the adjacent pin. Chains commonly used today are 1/2-inch pitch. The next number in the chain designation indicates the inside width of the chain. However, as chains have gotten narrower to fit between tighter spaced cogs, the outside chain width has become a more common measurement.

The 1/2" x 1/8" chains are often used on bicycles with a single rear cog. These include coaster brake and internally geared bikes, some BMX and track bikes. These bikes commonly have a single cog thicker than 2.6 mm. Because these chains are wider than derailleur type chains, they cannot be used for derailleur-equipped bicycles, as the spacing between the rear cogs is too narrow. Some single cog bikes can also use a narrower 3/32" chain while other single cog bikes, like BMX flatland/freestyle bikes, require a larger 1/2" x 3/16" chain.

Single Cog Chain Identification

Chain Type	Pin width in mm
1/2" x 1/8"	9 -10mm
1/2" x 3/32"	7.5 -8mm
1/2" x 3/16"	13mm +

Historically, a 1/2" x 3/32" chain was necessary for any bike equipped with a derailleur. Although the 1/2" x 3/32" label is still used on some modern derailleur chains, the value has become arbitrary. Originally, a 1/2" x 3/32" chain had an outside width of approximately 8.0 mm. As the number of cogs in a gear cluster has increased over the years from 5 to 9 and now 11, manufacturers have had to squeeze the cogs closer together to make room for additional cogs. The resulting narrower spacing between cogs requires narrower chains. For example, a Campagnolo 11 speed system currently requires 5.5mm width chain.

Derailleur Chain Identification

Chain Type	Pin width in mm
5 & 6 speed (1/2" X 3/32")	7.5 - 8.0 mm
7 & 8 Speed	7.0 - 7.5 mm
9 speed	6.5 - 6.9 mm
10 speed	5.9 mm
11 speed	5.5 mm

As you can see, a traditional 1/2" x 3/32" chain is over 2 mm too wide to work with an 11 speed system. The mechanic should therefore refer to the manufacturers' specifications when deciding which chain will work best with a given drive train. If this information is not available, you may consult the above chart combined with some careful measurements using calipers.

Chain Maintenance, Drivetrain Wear, & Replacement

Lubrication - Bicycle chains are subjected to tremendous loads and are exposed to the elements. It should come as no surprise then, that chains need a certain amount of maintenance, and also require periodic replacement. Chains should be cleaned when they have an excess of dirt or dust on them, and frequently lubricated as well. The maintenance necessary for your chain depends heavily on the frequency of use, riding conditions and riding style.

It is best to lubricate the chain whenever it is cleaned, and preferably before it becomes so dry that it makes noise. Excessive lubrication, on the other hand, causes the chain to attract dirt. The best lubricant to use depends a lot on the conditions that the chain is exposed to. Wetter conditions call for a heavier lube that won't get washed away easily. However, that same lubricant used in dry, dusty conditions would lead to the chain getting prematurely dirty, so a lighter lube would be in order. When applying lubrication, it is only necessary to lube the inside of the chain around the rollers and between the side plates. Lubrication on the outside of the chain is not only unnecessary, but will easily attract dirt. Wiping the outside of the chain with a rag will keep it dry and clean.

Chain Wear

Over time, as a chain is subjected to stresses, the rollers wear and the distance between each chain pin increases. This is due to the pinholes elongating or ovalizing from the torsional load of the cranks pulling on the chain. This is commonly referred to as chain "stretch", although obviously the chain isn't actually stretching. This condition can get bad enough that the chain pitch no longer matches the cog and chainring tooth profile, and the chain will actually begin to wear the cog and chainring teeth the same way. A chain costs much less to replace than a cassette and/or set of chainrings, so it is much wiser to replace the chain before it reaches this critical point. Also, if you wait too long, the new chain will no longer be compatible with the older worn-out cogs. The rate that the chain wears depends on many variables such as dirt, rider strength, hardness of materials, etc., so it's a good idea to check the chain often for wear.

Chain wear is detected by measuring either a section of the chain, or the entire length. There are a variety of tools available that measure chain length, but they only measure several inches of the chain at most. The smaller the distance measured, the more accurate that measurement must be. In order to get the most accurate reading of chain wear, the entire length of the chain should be measured. This procedure is often not practical in a shop environment, so most shop mechanics will use a chain wear tool. But if the chain is off the bike, it can be pulled taut and laid across a machinist's rule. By lining up the first pin on either the inch or half-inch designation line, and then observing how far the last pin of the entire chain deviates from the corresponding inch or half-inch line, we can accurately determine the extent of the wear. Less than 1/8" over the chain's entire length is acceptable. More than 1/8" is likely to be causing other drive train wear. This may call for replacement of the chain, as well as cogs and chainrings.

Cog and Chainring Wear

As cogs and chainrings wear, the spaces between the teeth elongate. The leading edge of each tooth on a chainring, and the trailing edge of each tooth on a cog, becomes undercut (or "hooked") by continuous torque by the chain. In extreme cases the tops of the teeth will begin to look pointed. This reduces efficiency in the drive train and can lead to shifting problems. If a chainring continues to be used in this condition, the underscoring will get to the point that the chain will get stuck on the tooth while shifting and not release from the chainring, causing the chain to jam. This is generally referred to as "chain suck." If any of these symptoms exists, replace the chainring.

Cog wear can be even harder to identify than chainring wear, and no tool exists that accurately measures it. Quite often a cog will be worn without being visibly damaged, and problems will not appear until a new chain is installed. The system may even appear to work well in a work stand, but under rider load will shift poorly and slip as the new chain attempts to engage the worn cog.

Chain Removal

When a chain needs to be removed, the chain is separated by the method dictated by the manufacturer. One method is the use of a master link (see figure 6), usually seen with 1/2" x 1/8" chains. A master link is a special link where the chain pins are permanently fixed to an outer plate, and a clip or plate snaps onto the protruding rivets. The clip type can be removed by gently prying with a screwdriver.

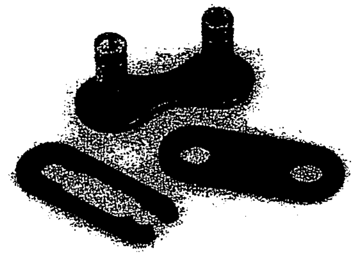

Fig. 6 Master link.

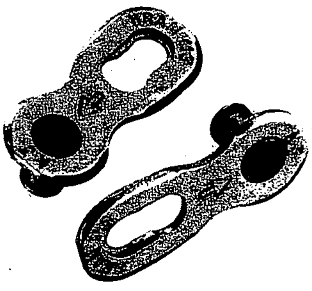

Fig. 7 SRAM special connecting plates.

Fig. 8 Park MLP-1.

Another type of connection method uses two interconnecting outer plates (each containing one pin) that interlock with each other (see figure 7). These special connecting plates are brand and speed specific, and may require specialty tools for removal (see figure 8). Some non-derailleur chains use this system, and all SRAM derailleur chains as well.

Some chains do not have a master link or special connecting links, and removal or installation of the chain requires that a factory installed chain pin be pushed completely out of the link. Then a new replacement pin (see fig 9) is used to reconnect the chain.The replacement pins, and tools used to intall them, are specific to each brand and number of speeds the drivetrain is designed for. Both Shimano and Campagnolo use special replacement pins.

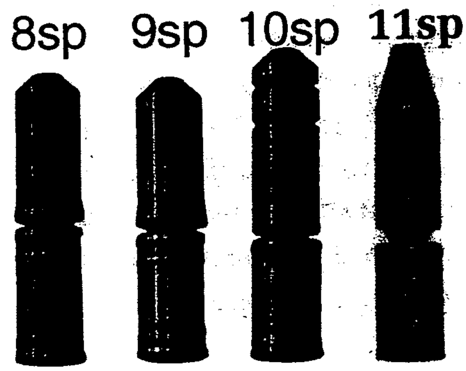

Fig. 9 Shimano replacement pins.

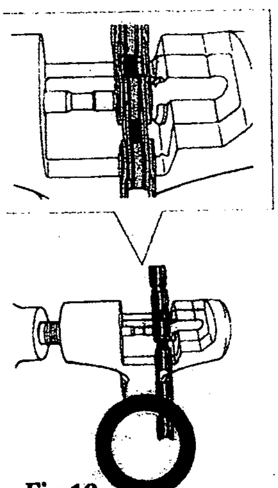

Fig 10

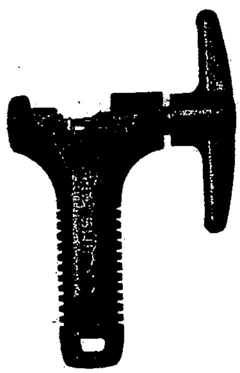

Fig. 11 Shimano chain tool.

Chain tools operate by holding the chain link in a small cradle (see figure 10), and then a plunger is driven against the chain pin to push it out. The same tool is used to push a new pin back in when reinstalling the chain. In some cases a manufacturer-specific chain tool may be required (see figure 11).

Some chains do not use replacement pins, so the pin only needs to be pushed through far enough to clear the inner link while still remaining attached to the opposite side plate. With this type of chain, the pin should not be pushed completely out. Also, which pin you choose to displace is inconsequential, although it is a good idea to never push the same pin out more than once.

Most new chains require that the chain pin be completely driven out, then replaced with a special connecting pin, a master link, or a special connectling plate set. When a replacement pin is required, it is important that the new pin match the width of the chain. Once installed, replacement pins should not be removed again. As mentioned before, it is important to consult the manufacturer's specifications for the correct method of reinstalling a chain.

Chain Sizing

Proper chain length is determined with all components mounted to the bicycle. New chains typically must be shortened to the correct size for a bicycle's gearing. It is important the chain be at least long enough to handle being engaged in the large chainring to large rear cog combination without binding. If the chain is too short to do this, the chain may bind, causing damage to the rear derailleur, rear dropouts, chainrings, or chain. If the problem occurs while the bike is being ridden, it could result in a crash and serious injuries to the rider. If the chain is too long, it will sag when engaged in the small chainring to small cog combination, and could skip.

Fitting a Chain

An easy way to determine chain length is to wrap the chain around the largest chainring and largest freewheel cog — without routing it through the derailleurs — and add two links (see figure 12). There are different ways of defining a link of chain, but at UBI a link is defined as a single pin-to-pin length of chain. Since each pin-to-pin length is 1/2" an easy way to remember this rule is to add 1" of chain.

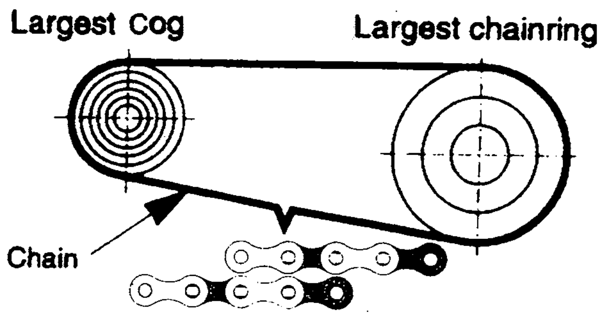

Fig. 12 - For proper sizing, route the chain over the big-big combination and add two pin-to-pin sections of chain.

Chain Sizing: Full Suspension Bicycles

On full suspension bikes the effective chainstay length changes as the frame moves through its travel. This needs to be taken into consideration when fitting a chain to the bike. It is recommended to cycle the rear suspension through its travel and measure any changes that occur to the chainstay length. Fit the chain with the chainstay at its longest measured distance. The chain should be checked again in both extreme gear combinations as the suspension moves through its travel.

STUDENT HANDS-ON:

Shimano Chain Removal and Measuring for Wear

Tools needed:
Chain tool
Park CC3 chain wear tool

Step 1 – Measure the chain for wear by using the chain wear indicators supplied before removing the chain. Measure this in several places on the chain.

Step 2 – Shift the derailleurs into the small, small combination.

Step 3 – Remove the chain using the appropriate chain tool.

Step 4 - Measure the chain width with calipers and record the width below. Consult the chart on page 4-8 to determine what type of chain it is (9 speed, 10 speed, etc.).

chain width ________mm chain type __________

STUDENT HANDS-ON:

Shimano Chain Reinstallation

Step 1 – Check chain length.

Step 2 – Route the chain through the front and rear derailleurs and around the cassette.

Step 3 - Use the installation pin provided by the instructor. Insert the pilot end first. Line up the chain tool plunger carefully with the installation pin. Push the pin inward until its profile matches that of the factory pin.

Step 4 - When finished with the installation pin, break off the protruding pilot with the bottom of the chain tool.

Step 5 - Check for stiff links (see figure 13).

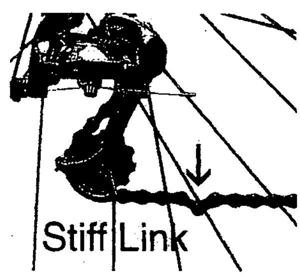

Fig. 13

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FREEWHEELS

A freewheel is a thread-on cog set that has a ratcheting mechanism that allows the cogs to drive the rear wheel forward, but also allows the wheel to turn freely when coasting or backpedaling. Before the development of freehubs, freewheels were used on all multi-speed bikes, and many single speed bikes. Now they are seen typically on single speed and entry-level bikes.

Most other bikes now use freehubs. It is easy to confuse the terms freewheel and freehub. Freehub refers to a completely different hub and cog arrangement and will be discussed later in this chapter.

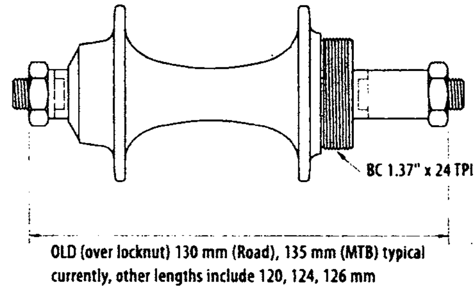

Fig. 14

Freewheel Bodies

Freewheel Thread Standards

ISO	1.375 x 24 TPI
English	1.370 x 24TPI
Italian	35mm x 24 TPI

The freewheel body is a ratcheting mechanism that consists of two subassemblies: an inner body, which is attached stationary to the hub, and an outer body, which spins freely around the inner body. The two bodies are separated by two sets of numerous small bearings at their interface.

The inner body has two or more stationary teeth called pawls. These pawls are held in an outward position by tiny springs. Because they protrude outward from the inner body, the pawls engage special teeth in the outer body when the rider pedals. When the rider coasts, however, they disengage and slide over the teeth, allowing the cogs to freewheel.

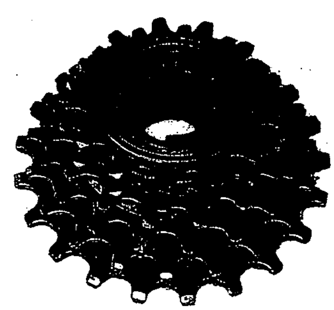

Fig. 15 - A typical freewheel

The pawls are surprisingly small, given the tremendous load they are required to support. Occasionally, the free-wheel body becomes contaminated by dirt or corrosion, and the pawls do not release and engage the outer body as they should. Usually, the freewheel is thrown out at this point, but another option is to overhaul the body. There is more information on this procedure in the Chapter 4 Appendix.

7 Speed maybe Freewheel or Free Hub

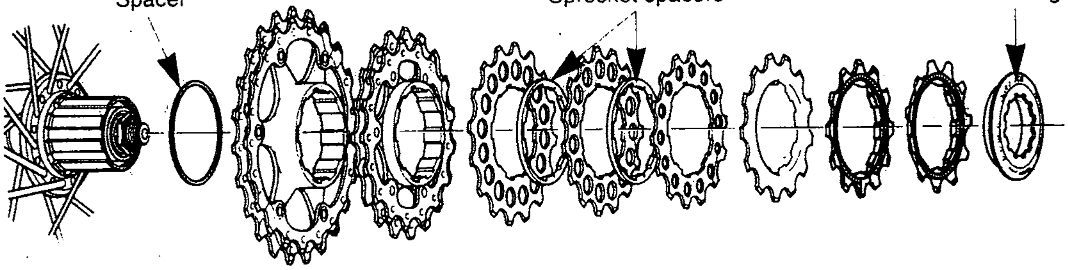

Fig. 16 - Exploded view of a cassette cog system

Cassette cog systems differ from freewheel systems in that the ratcheting mechanism is housed in a body that attaches directly to the hub. The separate cog set then slides onto the freehub body and is held in place by a threaded cog or lockring. The hub design is very different than a freewheel type hub. Hubs that use a cassette type cog set are referred to as "freehubs". One major benefit of the freehub is that its axle bearings may be located farther outboard, supporting the axle closer to the dropouts (see figure 17). This improved support makes the axle more resistant to bending or breaking under heavy loads.

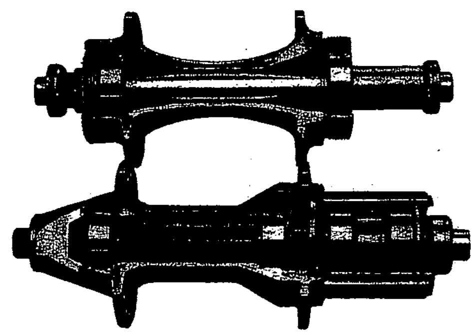

Fig. 17 - Exploded view of a freehub (lower) that utilizes cartridge bearings. Note position of bearings near dropouts.

To remove the cogs on a freehub, the cassette must be held with a chain whip, and the final threaded cog or lockring removed with either a second chain whip or special lock ring tool.

The cogs may come off individually or as subassemblies. Replacing individual cogs on a cassette system can be difficult or impossible, depending on the manufacturer. The cassette is typically replaced as a complete unit.

In order to remove the freehub body from a cup and cone hub, a hub overhaul is necessary. The axle assembly must first be removed by disassembling the axle locknut, spacer, and cone from the left (non drive side) of the hub. The axle can then be pulled out of the hub from the right (drive side). Once the ball bearings have been removed, a hollow bolt can be seen inside the body. Shimano and Shimano-licensed systems use a 10mm or 12mm hex wrench for removal. If the 10mm is not visible from the drive side, then an 11 or 12mm bolt will be used that must be accessed from the opposite side. Once the bolt is removed, the freehub body can be removed.

Cassette cogs need to be compatible with the freehub bodies. Both the spline pattern and body length must match. If in doubt, consult the manufacturer's literature. For additional information on freehub body length compatibility, consult Sutherland's Manual for Bicycle Mechanics, 7th Ed., pages 6-1 through 6-14.

STUDENT HANDS-ON:

Shimano Freehub Body Removal

Tools needed:

- Chain whip
- Cassette lockring tool
- Adjustable wrench
- 13 mm and 15 mm cone wrenches
- 10 mm hex wrench

Step 1 - Select a road bike.

Step 2 - Remove the rear wheel and examine the cassette system closely.

Step 3 - Remove the quick release.

Step 4 - Select the proper lockring tool and install it on the cassette lockring.

Step 5 - Use an adjustable wrench to loosen the lockring. Turn the wrench counter-clockwise while holding the cassette with the chain whip (figure 18).

Step 6 – Remove the lockring and lift the cassette off of the freehub body.

Step 7 - Remove the non-drive side locknut, spacers, and cone so that the axle assembly can be removed from the drive side of the hub.

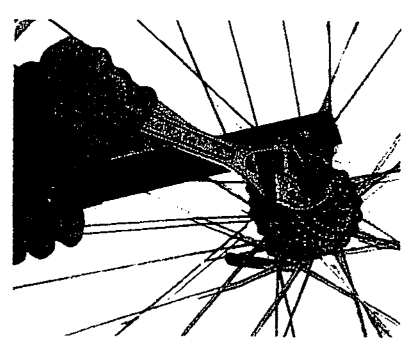

Fig. 18

Step 8 - Remove the ball bearings from each side of the hub.

Step 9 - Clean and inspect the bearing races for wear.

Step 10 - Use a hex wrench to loosen and remove the freehub mounting bolt. Remove the freehub body from the hub.

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STUDENT HANDS-ON:

Shimano Freehub Body Installation

Tools needed:

- Torque wrench
- Cassette lockring tool
- Adjustable wrench
- 13 mm and 15 mm cone wrenches
- 10 mm hex wrench

Step 1 - Grease the threads of the freehub mounting bolt and install the body onto the hub shell. Make sure the freehub body splines line up with the splines on the hub shell. Tighten the mounting bolt to manufacturer's specification.

Step 2 - Check the freehub body to ensure that it moves freely, and that the pawls are engaging.

Step 3 - Grease the hub bearing races and install the hub bearings.

Step 4 - Install the axle assembly from the drive side of the hub. Install cone, spacers and locknut. Adjust the hub for a small amount of play when the wheel is off the bike. The play should disappear when the wheel is back on the bike and the quick release lever is closed. It is important to do this adjustment before installing the cassette.

Step 5 - Install the cassette onto the freehub body.

Step 6 - Install the cassette lockring and tighten to the manufacturer's torque specifications.

Step 7 - Install the wheel on the bicycle.

Step 8- Have an instructor check your bicycle. If acceptable, the instructor will sign your daily checklist.

DT Swiss FREEHUBS

The DT Swiss 370/Onyx freehub shares some similarities with the Shimano. Both freehubs' mechanisms utilize a set of two pawls to drive the system, and a spring which retains the pawls and keeps them in an engaged position. The pawl spring on the 370 hub is much beefier and has a "leg" which helps to locate the spring in its proper position. Also, the Shimano freehub has two sets of 25 1/8" ball bearings, while the DT Swiss 370 hub utilizes a cartridge bearing on the outboard side of the body, and roller bearings in a retainer on the inboard side. Even though these systems are similar, the Shimano is considered to be a non-serviceable type of freehub because the tools necessary for this service are no longer available .

The DT Swiss star ratchet mechanism is completely different (figure 19). The star ratchet mechanism uses opposing ramps with springs on either side that keep the teeth of the ratchet engaged while moving forward. While coasting, the teeth on the ratchet are allowed to slip by pushing against the spring.

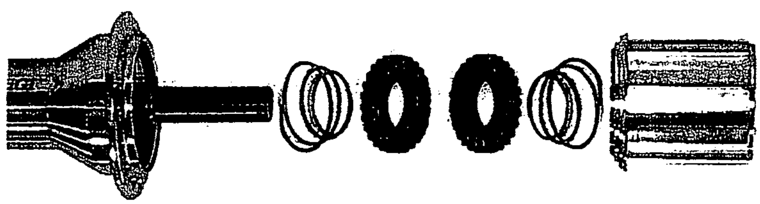

Fig. 19 - The DT Swiss star ratchet assembly

STUDENT HANDS-ON:

DT Swiss Star Ratchet Disassembly

Tool needed:
Axle vise

Step 1 Firmly clamp the drive side axle in axle vise.

Step 2 - Grasp the hub body firmly with both hands. While pulling upward, gently wiggle the hub body back and forth until the axle adapter comes free.

Step 3 - Pull the cassette body from the hub and remove the outer star ratchet spring, both star ratchets, spacer, and inner star ratchet spring.

Step 4 - Thoroughly clean and inspect all parts for wear.

STUDENT HANDS-ON:

DT Swiss Star Ratchet Reassembly

Step 1 - Firmly clamp the non-drive axle into an axle vise.

Step 2 - Lightly grease the drive side of the axle and spacer with lightweight suspension grease and slide the spacer onto the axle.

Step 3 - Install the inner star ratchet spring with large diameter side towards hub body (inner and outer springs are interchangeable).

Step 4 - Lightly grease both sides of the star ratchet with DT Swiss star ratchet grease

Step 5 - Install the star ratchet mechanism onto the axle, making sure that the teeth of the ratchets are facing each other.

Step 6 - Install the outer star ratchet spring onto the cassette with the large diameter side towards the inside of the freehub body.

Step 7 - Slide the freehub body onto the protruding drive side axle and twist slightly until the freehub body engages the star ratchet mechanism.

Step 8 - Lightly grease the inside of the axle adapter.

Step 9 - While holding the freehub body down, press the axle adapter onto the axle until it bottoms out. Check the axle for play.

Step 10 - Turn the freehub body counter-clockwise to verify that the ratchet mechanism is functioning properly.

STUDENT HANDS-ON:

DT Swiss 370/Onyx Freehub Body Disassembly

Tools needed:
17mm Wrench
Axle Vise

Step 1 - Clamp hub axle by the non-drive side in 10 mm aluminum axle vise.

Step 2– Use the 17mm wrench to remove the drive side locknut, spacer, and freehub body.

Step 3 - Clean all parts and inspect for wear.

STUDENT HANDS-ON:

DT Swiss 370/Onyx Freehub Body Reassembly

Step 1 - Apply a thin layer of DT Swiss grease to the bearing seat and inner freehub body.

Step 2 - Lightly grease the inside of the outer freehub body and slide it onto the axle. Rotate the outer body counter-clockwise so that it seats onto the hub body.

Step 3 - Slide the spacer onto axle and install locknut. Torque the locknut to manufacturer's specifications. Check the axle for play.

Step 4 - When you are finished, have an instructor check your work. If it is satisfactory, an instructor will sign your daily student checklist.

CHRIS KING RINGDRIVE ™ FREEHUBS

The Chris King freehub mechanism differs in many important respects from the traditional pawl and spring design seen on most freehubs. The proprietary RingDrive™ system utilizes two rings with toothed, ramped faces to engage the drive mechanism. One ring, called the driven ring, is held fixed in the hub shell. The other ring, called the drive ring, interfaces the driveshell assembly on which the cogs are mounted through a series of helical splines. While coasting, the ramped teeth on the drive ring and the driven ring are allowed to slip past one another. When force is applied to the pedals, the helical interface on the driveshell works to pull the drive ring towards the driven ring, engaging the ramped faces and transmitting torque to the wheel.

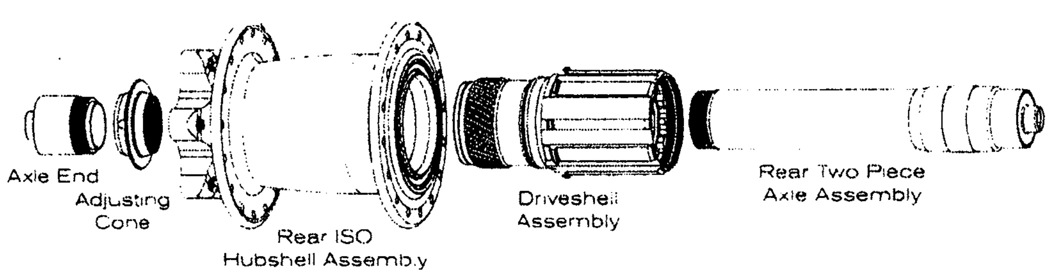

Fig. 20 - An exploded view of the Chris King RingDrive Freehub. Diagram courtesy of Chris King Precision Components.

STUDENT HANDS-ON:

Chris King Rear Quick-Release Hub Disassembly

Tools needed:

Two 5 mm hex wrenches

2.5 mm hex wrench

Chris King Hub Cone Adjusting Tool

Step 1 – Identify the hub axle type. The one-piece axle utilizes an adjusting clamp with a 2.5 mm hex nut on the non-drive side to adjust and lock the bearing preload. The two-piece axle utilizes an adjusting cone on the non-drive side to set the bearing preload and an axle end to lock the adjustment.

Step 2a – One-piece axle – Using a 2.5 mm hex wrench, loosen the hex bolt located on the adjusting collar. It is not necessary to completely remove the bolt.

Step 2b – Two-piece axle – Insert a 5 mm hex wrench into each axle end. While holding the right (drive-side) hex wrench stationary, turn the left (non-drive) hex wrench counter-clockwise until the assembly is loose. Unthread the axle end the rest of the way by hand and remove it from the axle.

Step 3a – One-piece axle - Unthread the adjusting collar and remove it from the axle.

Step 3b – Two-piece axle - Using the Chris King Hub Cone Adjusting Tool, unthread the adjusting cone and remove it from the axle.

Step 4 – Pull the axle from the drive side and remove it from the hub shell.

Step 5 – Grasp the hub in one hand and pull on the driveshell with the other hand to remove it.

Step 6 – Clean and inspect all parts. Pay particular attention to the helical splines on the driveshell assembly. These should be clean and free of any debris.

STUDENT HANDS-ON:

Chris King Rear Quick-Release Hub Reassembly

Tools needed:	
5 mm hex wrench	2.5 mm hex wrench
Chris King Hub Cone Adjusting Tool	Torque wrench
5 mm hex bit for torque wrench	

Step 1 - With the drive side of the hub shell facing you, lightly push down on the helically-splined drive ring with your finger to expose the toothed face of the ring. Apply a bead of Chris King RingDrive™ Lube to the teeth and allow the rings to spring back together. Wipe away any excess grease.

Step 2 - Apply several drops of light oil to the helical splines and the O-ring on the driveshell assembly. Apply a bead of RingDrive™ Lube to the helical splines.

Step 3 - Insert the driveshell assembly into the drive side of the hub shell. Rotating the drive shell clockwise as you insert it into the hub shell will help aid installation. Continue pushing until you hear a distinct click. This indicates that the driveshell is fully seated against the bearings.

Step 4 - Check for proper operation of the RingDrive™ mechanism by rotating the driveshell first counter-clockwise to freewheel, then clockwise to engage the RingDrive™.

Step 5 – Insert the axle threaded end first through the driveshell and push until the axle is fully seated.

Step 6a One-piece axle – Thread the adjusting collar on to the non-drive side of the axle clockwise until the adjusting collar just contacts the bearing. Using a 2.5 mm hex wrench, lightly tighten the adjusting collar hex bolt to lock the bearing adjustment. Do not overtighten. Check for play or binding.

Step 6b Two-piece axle – Using the Chris King Hub Cone Adjusting Tool, thread the adjusting cone on to the non-drive side of the axle clockwise until the adjusting cone contacts the bearing. Thread the axle end on to the non-drive side of the axle. While holding the drive side of the axle with a 5 mm hex wrench, use the torque wrench with a 5 mm hex fitting to tighten the axle end to 110 in-lbs (12.4 N-m). Check for play or binding.

Step 7 - When you are finished, have an instructor check your work. If it is satisfactory, an instructor will sign your daily student checklist.

GEARING

Now that 27 and 30 speed drive trains are commonplace, it can be difficult to keep track of all the different gear combinations, and the effect that replacement of any of the geared components will have. The relative ease or difficulty in pedaling a specific gear can be expressed by a gear inch measurement.

Using gear inches as a unit of measurement has its origins in bicycles from the 19th century. The Penny-Farthing or Ordinary bicycle had a large front wheel with cranks attached directly to the hub (see figure 21). When the rider pedaled, the front wheel turned. One complete revolution of the pedals resulted in one complete revolution of the wheel. How difficult it was to turn the cranks was determined by the size of the front wheel - the larger the diameter, the harder it was to turn. The rider had the difficult task of trying to add greater momentum to the larger mass.

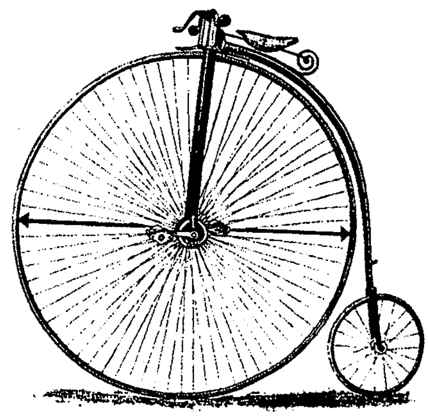

Fig. 21 - A penny farthing. The term "gear inches" derives from the diameter, in inches, of the penny farthing's front wheel.

If we measure the diameter of the front wheel of a Penny-Farthing in inches, it gives us the gear inches for that particular bicycle. So the term "gear inches" is based upon the diameter of a direct-drive wheel.

When a separate crank set was added to the bicycle, connected to the drive wheel by a chain and cog, the visual relationship between the drive wheel and gear size was lost. But our modern configuration of freewheels and chainrings is still mathematically related to the original Penny-Farthing.

Gear inches can be calculated by dividing the number of front chainring teeth by the number of teeth in the rear cog, and multiplying that number by the drive wheel diameter.

For example, the gear inch calculation for a 36-tooth front chainring and an 18-tooth rear cog on a mountain bike with a 26-inch wheel would look like this:

$$(36 \div 18) \times 26 = 52.0$$

This particular gear, then, is 52.0. This would be the same as if the bicycle were a Penny-Farthing with a 52.0 inch diameter front wheel. This doesn't mean that this particular gear will propel you along the ground a distance of 52.0 inches per revolution. To calculate the actual distance traveled with one complete revolution of the cranks, we would need to know the circumference of the wheel. For that, simply multiply the gear inch number by pi (3.14). In the above example, 52.0 x 3.14 = 163.28 inches of travel per revolution.

If you want to plot a gear chart for your own drive train, it is not necessary to do the arithmetic for every gear yourself, as gear inch charts are readily available in Sutherland's 7th Ed. pages 15-26 to 15-41. UBI also has a gear inch calculator on our web site.

It is not important to memorize these formulas or to even fully understand exactly what the numbers mean. What is valuable to remember is a 70 inch gear is harder to pedal than a 50 inch gear, and so on. The larger the number, the larger the drive wheel as it relates to the Penny-Farthing. By using these numbers as comparisons, you can determine good gearing set-ups for yourself and your customers with an appropriate range and as few duplicate gears as possible.

ADDITIONAL READING ABOUT CHAINRINGS, CHAINS, FREEWHEELS, CASSETTES, CARTRIDGE BEARINGS AND GEARING

The purpose of this list is to provide some alternate sources to help you learn the material covered in class. These reference materials may be checked out from the office for overnight or weekend use and returned the following morning. There is no requirement to do any of this reading. Read as little, or as much as you would like.

Sutherland's Handbook for Bicycle Mechanics (6th Ed):

Cranks, Chainwheels, Chain, Page 2-1 through 2-24

Freewheels, Freehubs, Pages 4-1 through 4-50

Hubs, Pages 10-1 through 10-12

Web Resources:

Cyclingnews.com

Tech section/Maintenance and Repair: Freehub Service

http://www.cyclingnews.com/tech/fix/?id=howfix_freehub

Sheldon Brown "Gain Ratios"

www.sheldonbrown.com/gain.html

United Bicycle Institute

On-line gear inch calculator

www.bikeschool.com/gearcalc/gearcalc.html

Chapter 4 Appendix

Freewheel Removal and Compatibility

The freewheel attaches to the hub by threading it onto the hub body. The freewheeling mechanism, though, prevents removal in the same manner. In order to remove the freewheel, a tool is necessary that engages internal notches or splines in the freewheel body. These tools have matching notches or splines machined on one end, and wrench flats on the other. There are many different notch and spline patterns, so it is important to select the proper tool for the specific freewheel being worked on. Often, an incompatible tool will appear to fit the notches or splines, but may damage either the freewheel or the tool if it is used.

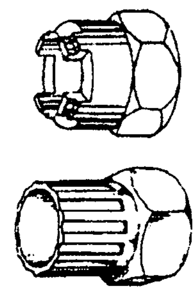

Fig. 18 - Freewheel removers

For this reason, it's a good idea to have a wide variety of freewheel tools on hand, and try all of them before you decide to remove the freewheel.

Freewheels are tightened on the hub by the rider's pedaling pressure, and can take a good amount of force to remove. If the freewheel tool slips during removal, it could break the tool's notches or those on the freewheel. Therefore, the freewheel tool will need to be secured against the freewheel. You can use the hub's axle mounting nut (if it is a solid axle) or quick release skewer (if it is a hollow axle) to accomplish this. The tool can then be held in a bench vise, and the wheel rotated counterclockwise, or else the tool can be turned with a large adjustable wrench to unthread the freewheel. Once the freewheel has broken loose, remove the axle mounting nut or skewer and continue unthreading the freewheel.

HOW-TO

Freewheel Removal

Step 1- Remove the rear wheel and inspect the freewheel to determine if it requires a splined type remover or a notched type remover.

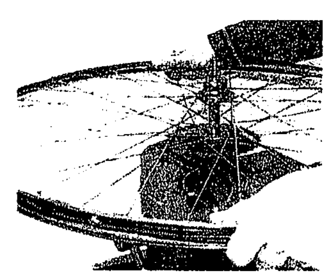

Fig. 19 - Removing a freewheel using a bench vise.

Step 2 - Select the proper freewheel remover. Check it in the freewheel to make sure it is an exact fit.

Step 3- Secure the remover to the freewheel by installing the quick release nut or axle mounting nut over the remover. This is very important!

Step 4 - Remove the freewheel using one of the following two methods:

1. Position the wheel in a bench vise with vise jaws clamped firmly around the freewheel remover's wrench flats (figure 19). Turn wheel counter clockwise just to break it free; or,

2. Attach a wrench to the freewheel remover's wrench flats and unscrew counter clockwise. Be sure to only break the freewheel free; do not unscrew all the way yet!

Step 5 - After breaking the freewheel free, remove quick release nut or axle mounting nut from the freewheel remover. Please note: Failure to remove the quick release nut or axle mounting nut may cause the freewheel to bottom out against the remover, causing permanent damage to the aluminum hub threads!

Step 6- Remove the freewheel remover from the freewheel and finish removing the freewheel by unscrewing with your hand.

HOW-TO
FREEWHEEL BODY OVERHAUL AND FREEWHEEL REASSEMBLY

Step 1 - Using either a Bicycle Research freewheel vise combined with one sprocket remover, or using two sprocket removers in opposition to each other, remove smallest cog on the freewheel and the spacer underneath it, if applicable. This cog is right hand threaded.

Step 2 - Determine the removal method of the remaining cogs, threaded or splined, and remove. Once removed, leave the cogs off.

Step 3 - Determine the best way to secure the freewheel body in order to unthread the fixed race by using one of the following methods:

1. If the freewheel body is the splined type, insert the proper splined freewheel remover into the back side of the freewheel, allowing enough protrusion of the wrench flats to engage in a bench vise; or,

2. If the freewheel body is the notched type, thread it back onto the hub finger tight.

Step 4 - Unthread the fixed race with a pin spanner. Remember, the fixed race has left hand threads! If the body is attached to the hub, break the fixed race free, then remove the body from the hub before complete disassembly. If the pin spanner slips, use a small punch and hammer to pre-loosen the race, then continue unthreading with the pin spanner.

Step 5 - Separate the inner and outer bodies. Ball bearings will drop out as you do this so hold the pieces close to the workbench.

Step 6 - Clean and inspect parts all parts for wear.

Step 7 - Apply a fine layer of grease in both ball tracks to hold the ball bearings in place.

Step 8 - Install as many 1/8" bearings as will fit around the circumference of each ball track, leaving out 1 or 2 when you get back to your starting point. It is important to install them all side by side to get an accurate representation of how much space is left at the end of the circle of bearings. When you are finished, there should be a small gap capable of holding 1 or 2 more balls, but do not fill this gap. Doing so will cause the body to have too many bearings.

Step 9 - Slip the outer body over the inner body, slightly rotating the outer body counterclockwise as you lower it over the inner body. This will allow the outer body to clear the pawls.

Step 10 - Tighten the fixed race with a pin spanner to manufacturer's torque specifications, being careful not to stack any bearings.

Step 11 - Lubricate the freewheel body by applying oil into the gap between the inner and outer body. Some freewheel bodies have oil ports on the outside for this purpose.

Step 12 - Apply a light coating of grease to the freewheel body and begin installing the freewheel cogs by installing the largest splined cog first, being careful to check for its proper orientation. Continue installing all remaining splined cogs and spacers.

Step 13 - Grease the threads of the body and install the threaded cog(s) starting with the largest, tightening with a sprocket tool as you install them.

Step 14 - Apply a thin layer of anti-seize or grease to the freewheel hub threads and carefully thread the freewheel onto the hub.The freewheel should thread on by hand very easily. If you feel resistance, back the freewheel off the threads and start again to avoid cross threading it.

Step 15 - Do the final tightening of the freewheel onto the hub using a sprocket tool.

Step 16 - Install the wheel onto the bicycle.

Chainline

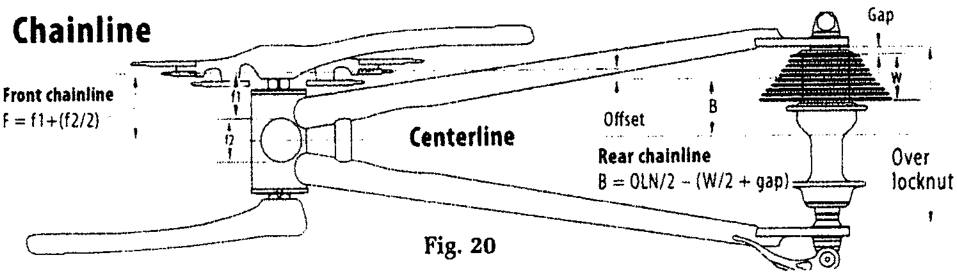

Fig. 20

Chainline is the relationship between the front chainring or chainrings and the rear cog or cogset. It is a measurement from the centerline of the bicycle to the chainring(s) and cogs.

When examining chainline on a multi-speed bicycle it is typically measured from the middle chainring on a triple crank set, or between the chainrings on a double crank set. On the back, it is referenced by the middle cog.

When chainline is examined on a single chainring bicycle it is typically from the center of the front chainring, and the center of the cog on the back (for a single speed), or the middle cog of the rear cog set.

Ideally, the midpoint of the front chainrings and the midpoint of the rear cog set will be the same distance from the center line of the bicycle frame. This ensures minimal chain deflection, lessening drive train wear and noise, and provides for precision shifting of the derailleur system.

Chainline can be measured or estimated by sighting along the length of the chain using the top tube of the frame as a guide. By comparing the distance from the edge of the top tube to both the rear cogs and the chainrings, you can roughly determine the chainline as it relates to the bicycle frame.

Just because a chainline error is detected is not necessarily a reason to correct it. There are very few bicycles that have perfect chainlines. Chainline errors can be difficult to correct, and the time and money sacrificed to such an operation is often not worth the end benefit. Usually it is only prudent to attempt to correct a chainline problem if a gross error exists, causing shifting problems or excessive drive train noise.

HOW-TO:

Measuring Chainline

Tool needed:
Vernier calipers

Step 1 - Using the vernier caliper, measure the outside diameter of the seat tube just above the front derailleur clamp.

_______________millimeters

Step 2 - Divide the seat tube diameter by 2.

_______________millimeters

Step 3 - Using the depth gauge portion of the vernier caliper, measure the distance from the side of the seat tube to the middle chainring.

_______________millimeters

Step 4 - Add your measurements from steps 3 and 4.
This is your front chainline.

_______________ front chainline

Step 5 - Using the I.D. jaws of the vernier caliper, measure the rear dropout spacing on the frame.

_______________millimeters

Step 6 - Divide that number by 2.

_______________millimeters

Step 7 - Measure the distance from the drive side lock nut to middle of the cogset.

_______________millimeters

Step 8 - Subtract the figure in step 7 from the figure in step 6.
This is your rear chainline.

_______________ rear chainline

Step 9 - Compare your finding from step 5 and step 8 to the manufacturers recommendations.

Step 10 - Using the frame alignment gauge, check the alignment of the frame.

_______________millimeters

Correcting Chainline Errors

If the chainline is determined to be causing problems in the drivetrain, minor corrections may be made by changing the length of the bottom bracket spindle . This will change the position of the chainrings relative to the centerline of the bicycle. If the BB is a square taper cup and cone design, a spindle of a different length can be installed. If the BB is a cartridge unit, the entire unit has to be replaced with a new one of a different spindle length. However, if the bike uses a two piece crankset, it will be impossible to change the spindle length. Before undertaking such a procedure, clearance between crank arms, chainrings and chain stays needs to be noted. For additional information about bottom bracket spindles, consult Sutherland's, 7th Ed., pages 4-6 through 4-23.

If correction at the bottom bracket is not possible, frame alignment should be checked. If the frame is misaligned enough to cause a severe chainline error that compromises shifting performance, the best recourse is to contact the manufacturer for a replacement frame.

Chapter 5

Derailleurs, Shift Levers, Cables and Housing

Objectives:

- Identify compatible shifting systems
- Calculate derailleur capacities
- Set-up and adjust the common shifting systems on both road and mountain bikes

Derailleur is a French term for the mechanism that moves the chain from one sprocket to another, literally derailing it from one cog to the next. Derailleurs in one form or another have been around since the late 19th century. As the term suggests, much of the early experimentation in derailleur design was done in France by companies like Cyclo, Huret and Simplex. According to historian Frank Berto, the first example of the modern parallelogram rear derailleur design was introduced by the French company Nivex in 1938. This design was later refined by other companies like Campagnolo, SunTour and Shimano into the slanted parallelogram derailleur now typical in the 21st century. Other derailleur system refinements over the last few decades have been instrumental in increasing the popularity of bicycle riding, making it much easier for beginning cyclists to master shifting.

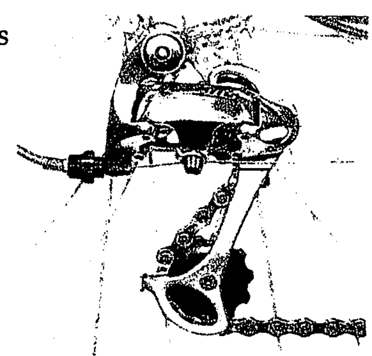

Fig. 1 A Shimano rear derailleur with a slant parallelogram design

Derailleur systems are composed of three integral parts:

- Control levers (the shift levers)
- The front and / or rear derailleur
- Shift cable and housing

All of these components must be compatible for optimum performance.

Until the introduction of indexed shifting in the 1980's, derailleurs were designed to be used with friction-type shift levers. This type of shift lever is held in place by a fastener that exerts just enough tension to hold the lever in place while in gear, but still allows the rider to shift. These friction systems provided no indexes where the shift lever stopped. The rider simply had to stop the lever by feel in order to get the desired gear. Since there were no indexes, it didn't matter how many cogs were on the rear hub, either. Compatibility was less of an issue, so mixing components from different manufacturers would often – but not always - yield acceptable results. For example, it was not unusual to see bikes equipped with Campagnolo derailleurs, Simplex shifters, a Regina chain and a SunTour freewheel.

Today, however, there are many compatibility issues when selecting derailleur system components, and the best performance is obtained by using components from the same manufacturer. For example, virtually all modern derailleur systems are indexed; that is to say, there is a distinct click when the rider shifts into a gear. The number of cogs on the cassette must correspond to the number of indexed positions in the shift lever. Add to this the proprietary spacing between cogs and it is easy to see compatibility is very important in the modern derailleur system. This chapter will deal with these issues, as well as proper removal, replacement and adjustment of derailleurs, shifters, cables and housing.

Rear Derailleurs

Rear derailleurs perform two basic functions. Their primary function is to move the chain from cog to cog. Their secondary function is to keep tension on the chain to compensate for different lengths of chain being engaged by different diameter cogs and chainrings. This is a function of the derailleur cage and the pulleys it houses.

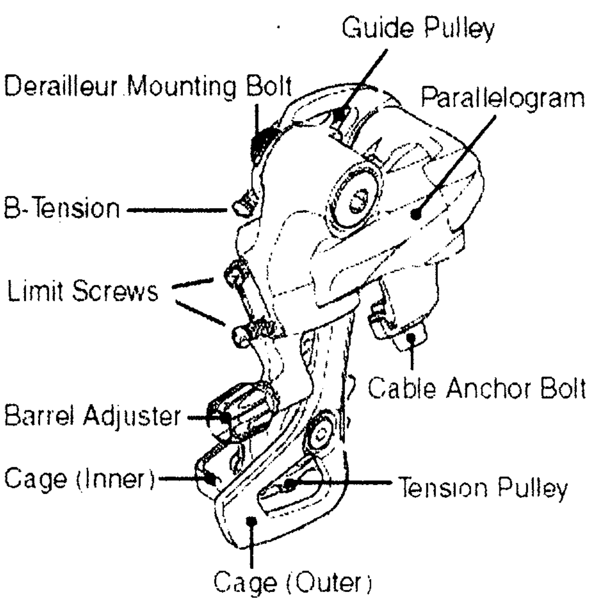

Fig. 2 - The components of a rear derailleur

There are two pulleys in a rear derailleur (figure 2). The upper pulley, which is closest to the cassette cogs, is called the guide pulley, so named because it "guides" the chain from cog to cog. The lower pulley is called the tension pulley. This pulley exerts tension on the chain by way of a spring mechanism located in the body of the derailleur, at the top of the cage. The tension spring puts rearward rotating pressure on the cage, keeping constant tension the chain. The length of cage required is part of the compatibility that we will discuss

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later in this chapter, and is determined by the range of gears for a particular bicycle. Generally speaking, road bikes with double chainrings and close ratio cassettes use shorter cage derailleurs while touring-type bikes and mountain bikes with triple chainrings and wide ratio cassettes require a longer cage.

The rear derailleur body is designed as a slanted parallelogram. This design moves the derailleur across the cogs at an angle, allowing it to closely track the profile of the cassette cogs. Rear derailleurs have either two or three spring mechanisms built into the derailleur to allow it to perform. One spring mechanism is a coil spring located within the parallelogram of the derailleur body. This spring acts as a counterforce to the shifter mechanism and cable and is called the return spring. The shift lever pulls the cable, which in turn moves the derailleur a specific distance. When the shift lever is returned to its neutral position, either one gear at a time or multiple gears at a time, the return spring causes the derailleur to also return to its neutral position. The shifter only pulls the derailleur in one direction: the return spring is what moves the derailleur in the opposite direction once cable tension is released through the shifter mechanism. The typical neutral position of a rear derailleur is underneath the smallest cog on the cassette (also called the tallest, or highest gear) In Shimano terminology this type of derailleur is referred to as a "top normal" rear derailleur. There is another type of Shimano rear derailleur called a "low normal" derailleur, because its neutral position is underneath the largest cog, or lowest gear.

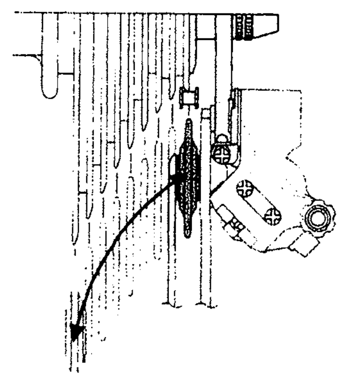

Fig. 3 - The slant parallelogram design allows the guide pulley to closely track the profile of the cassette.

As mentioned earlier there is sometimes a third spring in the body of a rear derailleur that allows it to rotate forward while shifting from larger cogs to smaller cogs. This wraps more chain around the smaller cogs for better tooth engagement.

Most rear derailleurs are attached to the frame via an M10 x 1 fixing bolt, and mounted to the derailleur hanger, which is part of the right drop out. Many frames now feature replaceable derailleur hangers that are bolted to the dropout. They are designed to deform in the event of a hard impact to avoid damage to the frame and/or derailleur. Other methods of derailleur mounting now exist. For example Shimano's component lines called Saint and Hone at one time featured rear derailleurs that attach directly to an oversized axle. This design eliminates the need for a hanger on the frame.

STUDENT HANDS-ON:

Rear Derailleur and Cable Removal

Tools needed:
5mm hex wrench
Chain tool
Cable cutters

Step 1- Shift both the front and rear derailleurs to their neutral position. Remove handlebar tape and set aside.

Step 2 - Cut the exposed rear derailleur cable between the cable anchor bolt and the barrel adjuster. For now, leave the remaining span of cable under the cable anchor bolt. Unless you are replacing the housing it is a good idea to trim any damaged cable before pulling the cable through the housing. Remove the cable from the shift lever assembly, and the shift housing from the bicycle. At this point remove the front derailleur cable in the same manner.

Step 3 – Identify the type of chain on the bicycle you are working on and remove it using the manufacturer's suggested method.

Step 4 – Loosen rear derailleur mounting bolt. Remove the rear derailleur and inspect for any wear or damage.

Rear Derailleur Compatibility and Interchangeability

When replacing or upgrading a rear derailleur, there are several areas of compatibility that must be taken into account to keep the system working properly. First, the new derailleur's cage length must be suitable for the gear range of the bicycle. This is called the derailleur capacity. Second, the derailleur must also be appropriate for the number of cogs on the cassette. Third, it must be compatible with the shift levers being used. Finally, because cables and housing are an integral part of the system, they must conform to the manufacturer's specifications.

Rear Derailleur Capacity

One of a rear derailleur's tasks is to keep adequate tension on the chain while pedaling. This is necessary because the amount of chain engaging any given chainring and cog combination changes with every gear shift. For example, when the chain is on the largest chainring and largest cog, the maximum length of chain is wrapped around that gear combination. Conversely, when the chain is on the smallest chainring and smallest cog combination the least amount of chain is wrapped around this combination.

When the chain is originally installed on the bicycle, it must be long enough to accommodate that large to large combination comfortably. But when the chain is engaged in the small to small combination, what happens to that extra section of chain? It is being "stored" in the length of the rear derailleur cage. The wider the gear ratio is, the longer the chain needs to be. The longer the chain is, the longer the rear derailleur cage needs to be to store this extra chain.

Every rear derailleur is designed for a specific capacity. Derailleurs with longer cages have greater capacity to deal with the wider gear ratios seen on mountain and touring type bikes. Shorter rear cages are designed for closer ratios such as the ones seen on a road race bike.

Determining the Total Gear Capacity on a Bicycle

When choosing a replacement derailleur or changing the bike's gearing, the derailleur's capacity and the bike's gearing must be compatible.There are some simple calculations you must make to determine whether the capacity requirement for the rear derailleur matches the bike's gearing: maximum chainring difference, maximum cassette difference, total capacity and maximum cassette cog.

Maximum Chainring difference – This is the difference between the number of teeth on the largest chainring and the number of teeth on the smallest chainring.

Maximum Cassette difference – This is the difference between the number of teeth on the largest cassette cog and the number of teeth on the smallest cassette cog.

Total Capacity – This is a calculation based on the preceding information. To get the Total Capacity required for the derailleur, add the maximum chainring difference to the maximum cassette difference.

Maximum Cassette cog – This is the number of teeth on the largest cassette cog.

Determining Rear Derailleur cage category (short / medium / long)

Once armed with the above information you can determine if a given derailleur is compatible with the bike's existing gearing, or new gearing compatible with an existing derailleur. First, determine the manufacturer's cage length designation. Cage length is a measurement from pulley center to pulley center. Manufacturers generally categorize their derailleurs into three groups, usually referred to as Long, Medium and Short. Long cage rear derailleurs have cage lengths greater than 80mm, short cage derailleurs are usually shorter than 70mm, and medium length cages, of course, fall somewhere in between.

Below is a capacity chart listing specifications from Shimano, SRAM and Campagnolo. Based upon this information and from the numbers of a bike's gearing, you can determine if a derailleur will handle the gears comfortably.

Cage Designation	Maximum Cassette Cog	Total Capacity
Shimano		
SS	30 (road)/28 or 36 (MTB)	34(road)/25(MTB)
GS	30(road)/36 (MTB)	40(road)/35(MTB)
SGS	36	43
SRAM		
Short	28(road)/36(MTB)	33(road)/30(MTB)
Medium	32(road)/36(MTB)	37(road)/35(MTB)
Long	36	47
Campagnolo		
Short	30	32
Medium	30	37
Long (triple only)	30	40

Note: the information in this table is for educational purposes and subject to change Consult the manufacturer for specific derailleur capacities and compatibilites as they can change within models and from one model year to another.

Here is an example of how to use this information. A customer brings a mountain bike into a shop, and wants to swap the bike's existing Shimano long cage (SGS) derailleur for a Shimano mid cage (GS) derailleur. The customer doesn't want to change any other drivetrain components. An inspection of the bike shows an 11-34 rear cassette and a triple crankset with chainrings of 44-32-22 teeth.

Recall that there are measurements to take of the existing drivetrain to determine if the customer's desired new derailleur will work: total capacity (which is based on maximum chainring difference and maximum cassette difference) and maximum cassette cog.

Maximum chainring difference - The customer has 44-32-22 chainrings, so this is 44 -22, for a maximum difference of 22 teeth.

Maximum cassette difference - The bike has an 11-34 rear cassette, so this number is 34 - 11, or 23 teeth.

Total capacity -This is the sum of maximum chainring difference and maximum cassette difference. 22 + 23 = 45 teeth.

Maximum cassette cog - This is 34 teeth.

In the chart, this mid cage (GS) derailleur's numbers are:

Maximum cassette cog – 34 teeth

Total capacity – 33 teeth

The new derailleur the customer wants to use will handle the maximum cog on the customer's existing cassette. However, the new derailleur's total capacity is too small for the existing drivetrain's total capacity. Therefore the customer will not be able to use the mid-cage derailleur without changing the bike's gearing.

Additional Rear Derailleur Compatibility Concerns

The rear derailleur hanger length is the measurement from the center of the rear axle to the center of the derailleur mounting hole (see figure 4). With a longer hanger the derailleur is positioned lower and farther away from the cogs on the cassette. This aids with wider ratio cassettes and prevents interference when shifting into the largest cassette cog. Generally speaking, road bikes designed for closer ratio cassettes will use a shorter derailleur hanger. Mountain bikes and touring-type bikes designed for wider ratios will have a longer hanger.

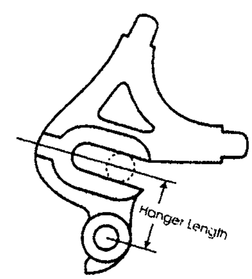

Fig. 4 - Derailleur hanger length

Introducing another manufacturer's components into a gear system, or even from a different component group by the same manufacturer, should be undertaken with care. Contemporary drivetrains are engineered as systems. In fact, many manufacturers, such as SRAM and DT Swiss, design components to be specifically compatible with various Shimano components. Nonetheless, it is always important for the mechanic to verify the suitability of such a component by checking with the manufacturer before installation.

Even when using components from the same manufacturer, compatibility can still be an issue. For charts on cassette interchangeability, see the Sutherland's handbook, 7th edition, chapter 6.

There are still other compatibility issues to consider.The bicycle must have a chain with the correct length and width for the given drive train (see Chapter 4). Also, proper cable and housing must be routed and installed correctly.

STUDENT HANDS-ON:

Derailleur System Compatibility

Step 1 – Determine the Maximum Chainring difference by subtracting the number of teeth in the smallest chainring from the number of teeth on the largest chainring.

Maximum Chainring Difference = 18 teeth 42 24

Step 2 – Determine the Maximum Cassette cog difference by subtracting the number of teeth on the smallest cog from the number of teeth on the largest cog

Maximum Cassette Cog Difference = 25 teeth 36 11

Step 3 – Determine the Total Capacity of the drivetrain by adding the Maximum Chainring difference to the Maximum Cassette cog difference.

Total Drivetrain Capacity = 43 teeth

Step 4 – Record the Maximum Cassette cog (the number of teeth on the largest cassette cog)

Maximum Cassette Cog = 36 teeth

Step 5 – Using the information gathered in steps 1 – 4 consult the appropriate manufacturer's section in the table provided earlier to determine the derailleur's compatibility to the gear range on the bicycle.

Rear Derailleur Hanger Alignment

Figure 5 illustrates an example of what can happen if the bicycle takes a fall on the right side. This can cause the derailleur to hit the ground, which, in turn can bend the derailleur hanger inward. This makes it impossible to adjust the rear derailleur system properly and must be remedied before the derailleur is installed and adjusted. There are two conditions that must be met before installation and/or adjustment can be made

- The dropouts must be parallel to one another
- The derailleur hanger must be parallel to the cassette cogs

To realign the derailleur hanger, remove the rear derailleur, then install a hanger alignment gauge into the hanger threads (see figure 6). Once installed the gauge extends outward from the hanger toward the rim. It is designed in such a way that the gauge is free to rotate so it will run parallel to the rim The derailleur hanger alignment tool acts as a reference tool as well as the straightening tool.

If the hanger is properly aligned, the gauge will remain the same distance from the rim throughout the rotation. If the hanger is bent, the gauge will be closer to the rim in some sections and farther from the rim opposite these locations. When using the hanger alignment gauge it is recommended to rotate the wheel with the gauge, for example, at the valve stem. This will ensure that you don't get an inaccurate reading due to a wheel that is out of true. If the derailleur hanger requires straightening, use the gauge to make corrections. Bending a metal is often referred to as "cold setting." This should only be attempted on a steel frame, or a frame with a replaceable aluminum hanger. In the latter case, the cold setting should only occur once. Any additional cold setting runs the risk of the material failing.

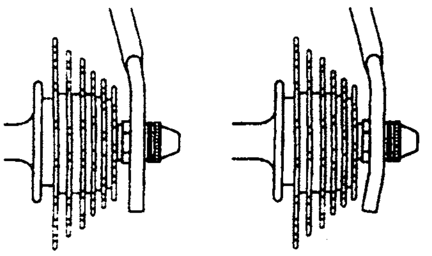

Fig. 5 -A bent derailleur hanger (right)

It is also important to note the frame's construction material before making any attempts to cold set a derailleur hanger. If the frame is steel , cold setting may be possible. Titanium frames do not respond to cold setting because the material is so difficult to bend. Carbon fiber and aluminum frames should never be cold set.

If a hanger is badly bent, distortion can occur in the derailleur mounting hole, causing damage to the threads. If the hanger is replaceable, the best option is to install a new hanger. If a new replaceable hanger is not available, or the hanger is not replaceable, the first step is to run a threading tap through the hole (this is a 10mm x 1mm tap). If the threads are damaged beyond repair there are thread repair kits available that utilize a thread coil insert. Another option would be to enlarge the hole and install a Dropout Saver "T - nut" into the derailleur hanger. These last resort-type of repairs were much more prevalent before the advent of the replaceable hanger, and as with cold setting would be much more successful on steel frames.

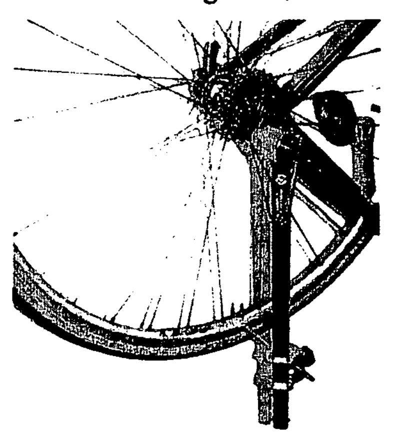

Fig. 6 - A derailleur hanger alignment gauge

Rear Derailleur Limit Screw Adjustment

There are two limit screws on every rear derailleur. These are used to limit the range of the rear derailleur to work within the range of the cassette. These limit screws are often marked with an H and an L representing high and low gears. It is best to adjust the limit screws while viewing the derailleur from the rear of the bicycle.

To adjust the high limit screw, use the appropriate tool, usually a screwdriver or small hex wrench. Turn the screw back and forth while viewing the guide (upper) pulley from the rear. You should see it moving laterally within a small range, underneath the smallest cog. A good starting point for the adjustment is to center the guide pulley directly under the smallest cog (see figure 7).

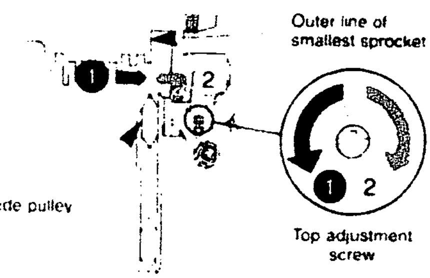

Fig. 7 - Adjust the high limit screw so the guide pulley aligns to the outside edge of the smallest cog.

To adjust the low limit screw, insert the correct tool, turning the limit screw with one hand while pushing the derailleur inward with the other hand. It is important to move the derailleur all the way inboard until it stops. Note: With some wider range cassettes using cogs larger than 28 teeth the guide pulley can contact the largest cog, so make sure when you move the derailleur inboard, it is hitting the limit screw and not the cog itself. Now you can turn the low limit screw back and forth, again ,viewing the derailleur from the rear. You will notice it moving laterally underneath the largest cog in the same manner as with the high limit screw adjustment. A good adjustment here will center the guide pulley under the largest cog. For best accuracy position the guide pulley as close as possible to the cog (see figure 8).

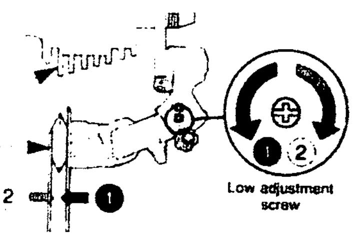

Fig. 8 - Adjust the low limit screw so the guide pulley aligns under the largest cog.

STUDENT HANDS-ON:
Rear Hanger Alignment Inspection, Derailleur Installation and Limit Screw Adjustment

Tools needed:

- Dropout alignment tool
- Derailleur hanger alignment tool
- Torque wrench
- 3/8" drive 5mm hex wrench
- Screwdriver

Step 1 – Check dropout alignment. Next, check derailleur hanger alignment. If you feel the hanger alignment is bad enough to warrant correction, consult an instructor first. *Do NOT cold set hanger without Instructor input.*

Step 2 – Lubricate the threads of the derailleur mounting bolt, and install the rear derailleur onto the hanger. As you tighten the bolt, be sure to hold the derailleur body upward and rearward to avoid damaging the stop plate against the hanger. Tighten the mounting bolt to the manufacturer's torque specification.

Step 3 – Adjust the high limit screw so that the guide pulley is centered just to the outside edge of the smallest cog (See figure 7).

Step 4 – Adjust the low limit screw so that the guide pulley is directly underneath the largest cog. As mentioned earlier, you will need to actuate the derailleur by hand, in order to complete this step. Do not install cable yet (See figure 8).

Front Derailleurs

Like rear derailleurs, the front derailleur moves the chain as well, but from chainring to chainring. This is no easy task, for several reasons. The difference in size from the smallest chainring to the largest makes it difficult to derail the chain smoothly and efficiently. Also, the derailleur is positioned farther from the chainrings and, unlike the rear derailleur, does not have a guide pulley to help facilitate the shift. Lastly, the chain is shifted while under tension, making it more difficult to disengage from the chainring. The front derailleur consists of a rectangular cage attached to a linkage which is activated by the cable. The design of the linkage not only allows the cage to move inward and outward, but also upward and downward. The cage height and position will therefore adjust to the size of the chainring it is shifting into. This action helps to compensate for the difference in size between the chainrings.

The cage consists of an outer plate and inner plate (figure 9). Cage design is based on the type of gearing being used. If the crank set has two chainrings, as in a road racing bike, the inner and outer plates of the derailleur will be similar in size. However, the inner plate will be positioned in such a way to be closer to the smaller chainring. On a bicycle equipped with three chainrings, the inner plate will be larger (taller) and positioned and shaped in such a way to closely follow the much smaller radius of the additional chainring.

Front Derailleur Compatibility and Interchangeability

There are several areas of compatibility a mechanic must consider when replacing or upgrading a front derailleur. A significant compatibility issue is whether the derailleur is designed for a double or triple crankset. Using the incorrect front derailleur for a given crank set could result in very poor shifting performance. For example, using a "triple" compatible front derailleur with a double chainring *set up* could cause the exceptionally tall inner cage plate to contact the teeth of the smaller chainring when shifting into the large chainring. Conversely, using a "double" compatible front derailleur with a triple crank set would cause very poor shifting performance when shifting from the smaller chainrings to the larger ones. This is because the inner cage plate would simply be too far away from the radius of the smaller chainring teeth to facilitate an efficient shift. Front derailleurs are further categorized as "road" or "MTB," based on the the type of crankset with which they'll be used. Front derailleurs designed for road triples may be incompatible with MTB triple cranksets, and vice versa, again because of the radius differences between road and MTB chainrings.

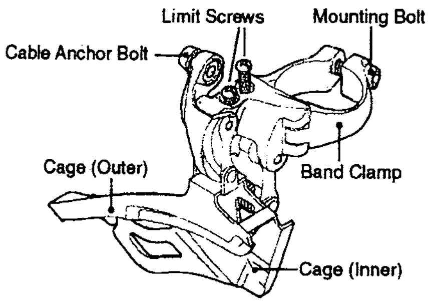

Fig. 9 - The components of a front derailleur.

The use of compact road cranksets (typically with double chainrings of 34 and 50 teeth) may necessitate a compact-specific front derailleur. This is due to the fact that the radius of the cage on a derailleur designed for a standard road crank may be too large to easily shift from the 34 to the 50 tooth chainring on a compact crank.

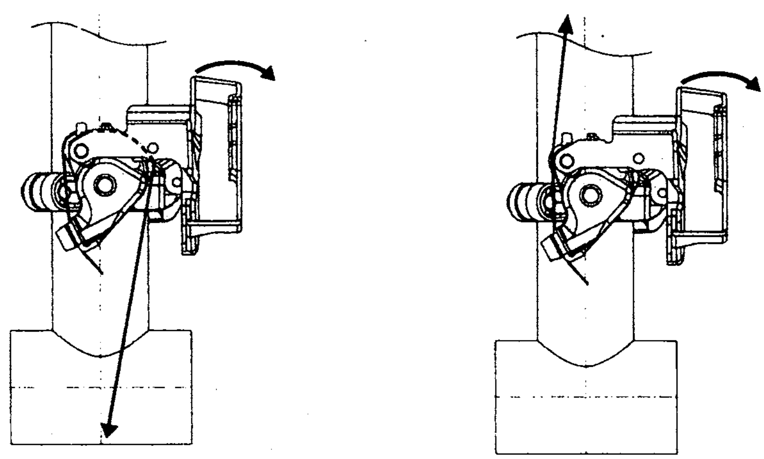

Fig. 10 - Left: Bottom pull front derailleur. Right: Top pull front derailleur

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Some manufacturers' compact crank designs require a compact-specific front derailleur, while others do not. Therefore it is important for a mechanic to consult the manufacturer's literature when installing a compact crankset.

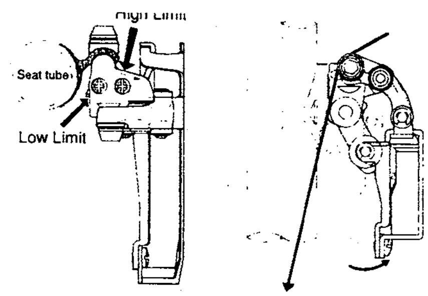

Fig. 11 - "Braze-on" style of front derailleur mounting.

The method of attachment to the frame is another compatibility concern. Most front derailleurs are installed by clamping around the seat tube of the frame. Since seat tubes come in a variety of diameters, so must the derailleur band clamp. The most common seat tube diameters and corresponding band clamp diameters are 28.6mm (1-1/8") 31.8mm (1-1/4") and 34.9mm (1-3/8"). Measuring the outside diameter of the seat tube is all that is necessary to determine the correct derailleur clamp size. Another method of attachment uses a special plate which has been attached to the seat tube. Depending on frame material, this plate is welded, brazed, bonded, bolted or even riveted to the tube This requires a front derailleur specially designed for this type of plate, to which the derailleur bolts directly. This type of design, commonly referred to as "braze-on," is most often found on road racing bikes (figure 11). Shimano makes another type of front derailleur design which does not attach to the seat tube at all. These derailleurs have a special bracket that mounts between the bottom bracket shell and the fixed cup of the bottom bracket. These are called "E – Type" front derailleurs (figure 12) and are primarily seen on city bikes and certain types of full suspension mountain bikes which have drastically altered or missing seat tubes.

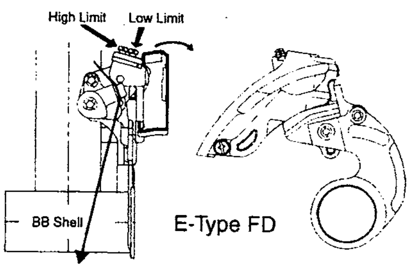

Fig. 12 - E-type front derailleur

Another area of compatibility is whether the front derailleur is a top swing or bottom swing. Figure 11 shows a bottom swing derailleur, and figure 13 a top swing. A top swing derailleur has a clamp that is lower than a bottom swing derailleur's clamp, and this may create some compatibility issues when swapping from one derailleur design to another on a very small frame or a full suspension mountain bike.

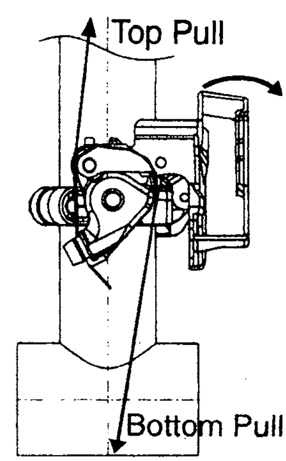

Fig. 13 - A dual pull front derailleur

Another area of compatibility that must be addressed is the direction that the cable pulls from. This refers to whether the cable routing is from the top of the bicycle or from the bottom. Cables routing from the top must be coupled with a "top pull" front derailleur. Cables routed from the bottom must be coupled with a "bottom pull" front derailleur. Many newer mountain bike front derailleurs come designed as a "dual pull" type derailleur, meaning they have a cam mechanism designed to work with either type of cable routing (figure 13).

Another compatibility consideration is chainline, which is the relationship of the centerline of the frame to the centerline of the crankset. This is measured from the center of the seat tube to the centerline of the middle chainring. Every front derailleur has a front chainline specification from the manufacturer, and the bike's chainline should fall within +/- 2 mm of this specification. As an example, the chainline for a Shimano Ultegra 6603 triple front derailleur is 45 mm. Therefore, the front chainline of the bicycle on which this derailleur will be used should be +/- 2 mm, or between 43 and 47 mm to ensure the performance the manufacturer intended. If shifting problems are encountered, a mechanic can measure the chainline. However, if chainline is determined to be the cause of the problem, there is little that can be done with modern componentry. If all possible fixes have been explored, a call to the manufacturer of the frame may be the mechanic's only recourse.

Front Derailleur Capacity

Like rear derailleurs , front derailleurs also have specific capacity ranges that are designed to work with specific chainring sizes.

Front derailleur capacity is calculated by subtracting the number of teeth on the smallest chainring from the number of teeth on the largest chainring. Using this number, you can determine a front derailleur's suitability for a given set of chainrings. Manufacturers will specify a derailleur's capacity, and may also specify the largest big chainring that can be used with the derailleur, as well as the maximum difference between the large and middle chainrings in a triple crankset.

As an example, a customer has a road bike equipped with a Campagnolo compact road double crankset, and wants to change to a Campagnolo road triple to gain some additional gear choices. By consulting the manufacturer's literature, you find that Campagnolo lists a capacity of 16 teeth for the compact front derailleur currently used on the bike. Further, Campagnolo specifies that the front derailleur capacity required for its road triple crankset must be 23 teeth. In this example, the customer's existing front derailleur will not work with the new road triple crankset.

Many improvements in front derailleur performance have come at the expense of compatibility. Front derailleur cages now follow the radius of the chainring much more closely, meaning the gearing of the crankset must match what the front derailleur was designed for. A deviation of the gearing means at best a sacrifice in performance and at worst interference between the derailleur cage and the chainrings.

STUDENT HANDS-ON:

Front Derailleur Removal and Compatibility

Tools needed:
5mm hex wrench
Vernier caliper

Step 1 - Unbolt and remove the front derailleur from the frame. Note: If front derailleur is a bottom bracket mounted design, leave it attached to the frame.

Step 2 - Determine the difference in chainring teeth by subtracting the number of teeth on the smallest chainring from the number of teeth on the largest chainring.

Chainring Difference = 18 teeth

Step 3 – Measure the seat tube diameter of the frame to determine the proper size derailleur clamp required.

Front Derailleur Clamp Diameter = 35.4 mm ÷2 17.7

Step 4 – Determine the derailleur's cable pull direction Bottom

Step 5 – Calculate the chainline of the system by measuring the distance from the middle chainring to the seat tube and add 1/2 the diameter of seat tube (see Figure 14).

Front Chainline = 51.3 mm

34.6 mm
- 1
33.6 mm

Chainline

F=F1-1+(dia/2)

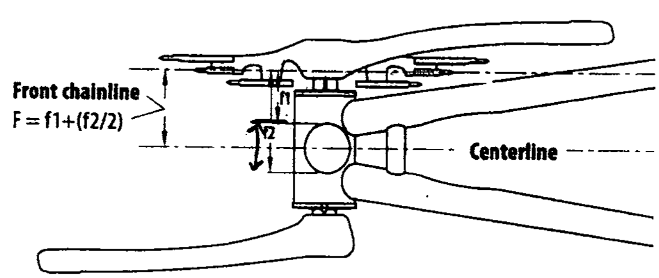

Fig. 14 - Measuring front chainline

chainring is 2 mm wide

Step 6 – Using the information gathered above, consult the appropriate manufacturer's information to determine the derailleur's compatibility to the gearing on the bicycle.

Note: *Do not reinstall the derailleur yet.*

Bottom Brackets on 3 piece could get a longer/shorter to change chainline

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FRONT DERAILLEUR INSTALLATION

When reinstalling the front derailleur, it must be placed in a position that will provide the best shifting performance possible. In most cases the mechanic has control over two factors in the front derailleur position: the height of the derailleur in relation to the chainrings, and the angle of the cage in relation to the chainrings.

Proper height is critical to good shifting performance. If the cage is set too high, shifting performance suffers due to mis-alignment of the shifting platforms. If it is set too low, the cage will actually contact the chainring teeth when a shift is attempted. Proper derailleur height is achieved when the bottom edge of the outer cage plate is set to a range of 1 to 3 millimeters above the tallest teeth on the largest chainring (see figure 15).

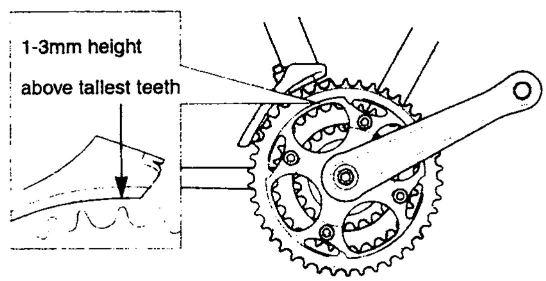

Fig. 15 - Setting proper height of the derailleur

To set the proper angle of the derailleur, position the outer cage plate to run parallel to the largest chainring. This may be performed more accurately by sighting down from the top of the crankset and using the large chainring as your straight edge (see figure 16). You may need to hold the derailleur in position while adjusting the angle. Be careful not to change the derailleur height while adjusting the angle.

The final adjustments will take place after the chain is installed and the rear derailleur system is functioning properly.

STUDENT HANDS-ON:
Front Derailleur Installation

Tools needed:
Torque wrench
3/8" drive 5 mm hex wrench
5 mm hex wrench

Step 1 – Apply a small amount of grease to the threads of the derailleur fixing bolt, and install the front derailleur onto the frame. For now, secure the derailleur just tight enough to hold it in place, yet still allow minor adjustments up and down, and rotational adjustments for cage angle.

Step 2 – Adjust the height of the front derailleur cage from 1 to 3 millimeters above the tallest teeth of the large chainring (see figure 15).

Step 3 - Adjust the angle of the front derailleur cage so the outer cage plate is parallel to the large chainring. You may need to actuate the derailleur outward to do this properly (see figure 16).

Step 4 – Secure the front derailleur to the frame. Tighten the clamp bolt to the manufacturer's torque specification.

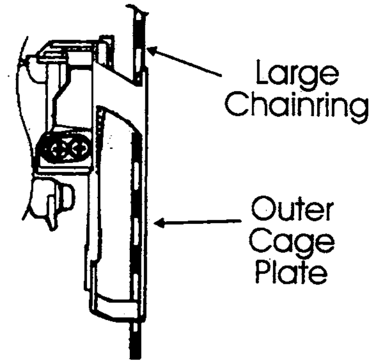

Fig. 16 - Proper angle of the derailleur cage.

SHIFT LEVERS

Although there are many types of shift levers for both, mountain and road bikes, the basic function remains the same – spooling cable and releasing cable to actuate the derailleur.

There are three basic types of shift levers used on bicycles – friction, ratcheting and indexing. Friction type shift levers are now rare; however you will encounter them on older bikes, especially pre-1980's road bikes. They are simply a lever held in place by a bolt, which exerts just enough tension to hold the lever in place while in gear yet still allows the user to move the lever while shifting.

Ratcheting type shift levers are used on some twist style front shifters and Campagnolo Ergo front shifters. Ratcheting levers are similar to indexed levers except the clicks are not meant to move a derailleur into a precise position. The ratcheting mechanism is simply designed to make it easier to shift with less friction. Ratcheting shifters offer a large number of index points that allow the rider to fine tune (or "trim") the position of the front derailleur over the chainrings. Each click does not correspond to a particular gear position, however. For example, a Campagnolo Centaur front shifter has 12 index spots to cover up to three chairings.

Nearly all shift levers today are indexed. This means the shift lever snaps into, and out of, precise detents located inside the shift lever, spooling a precise amount of cable with each shift. This causes the derailleur to move from cog to cog or, chainring to chainring, just the right amount to fully engage the teeth. Index systems take much of the guesswork out of shifting and allow even beginning cyclists to quickly master shifting.

Shift levers can be mounted in a variety of locations, depending on their design. For road bikes, there are levers designed to mount on the stem, downtube, or bar end, and shift levers integrated into brake levers (these are often called control levers). For mountain bikes there are shifters designed to be mounted above the handlebar (commonly called thumb shifters), below-the-bar levers (referred to as trigger shifters), twist-style shifters, and dual control levers.

DERAILLEUR CABLES and HOUSING

Derailleur cables and housing have evolved to meet the demands of indexed shifting systems. Compared with cables and housing of the friction-shifting era, cables are now smaller gauge (diameter) and smoother, while the housing is much stiffer. The correct cable and housing combination must be used with a given derailleur system in order for the system to function properly. Also, when replacing cables on an unfamiliar shift lever, carefully note the routing before you remove the old cable.

Cables – Although derailleur cables may look like a single wire they are actually composed of dozens of strands of fine wire that have been wound around each other in a helical pattern. This design makes the cable very flexible and very strong. There are two materials used in the production of the cables typically found in the bicycle industry, zinc treated steel and stainless steel. Zinc-coated cables are usually found on low- to mid-priced bicycles. Stainless steel is usually reserved for cables on higher end bicycles, or in areas where high resistance to corrosion is required.

The smoothness of the surface of the cable can have a significant impact on performance. Die-drawn versions of both zinc coated and stainless steel cables are available. Die-drawing is a process that smoothes the outer surface of the cable to reduce friction inside the cable housing. Die-drawn cables are also sometimes coated with a slick material such as Teflon or Gore-Tex.

Derailleur cable diameters vary. A cable designed for an older friction style system would be about 1.6mm in diameter, whereas cables used in indexed systems are typically about 1.1 or 1.2 millimeters in diameter.

Housing – Housing is made up of larger gauge wires that are formed into a tube and then covered with a plastic sheath. There are two types of housing available: flat wound housing and compressionless housing (see figure 17).

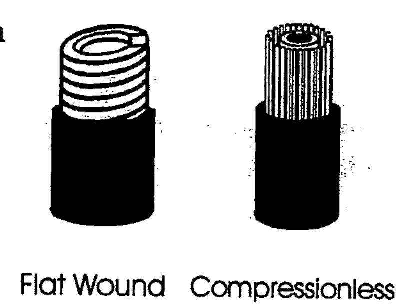

Fig. 17 - The two types of cable housing

Flat wound housing compresses and is still therefore only suitable for older friction-style derailleur systems and for brake systems (See Chapter 6). It compresses too much to be suitable for indexed systems.

Compressionless housing, does not compress lengthwise under load. This allows the cable to pull the derailleur the specific amount required for an indexed system to function. Without compressionless housing it is impossible to adjust an indexed system properly.

Most housing is available with a plastic liner to reduce friction. In fact, with compressionless housing it is a must. It is also vitally important to use housing end caps or ferrules on the ends of compressionless cable housing . Failure to do so will eventually cause the individual wire strands that make up the cable housing to migrate out of the plastic sheath and poke through the cable stop of the frame or the barrel adjuster. This will cause the indexing to go out of adjustment.

Important: Compressionless housing in general is only intended for use in derailleur systems. Using it in a braking system is dangerous because the housing does not have the burst strength required to withstand the loads associated with a cable operated braking system.

When determining the length of housing required for a given bicycle, keep the housing as short as possible while still allowing proper movement of all associated components within the system. Housing that is too long can increase friction within the system. Housing that is too short can bind or kink when the handlebars are rotated through the full range. Proper length housing is just long enough to enter and exit all stops smoothly without any abrupt bends.

Cable Lubrication

There are pros and cons to lubricating derailleur cables. A small amount of grease applied to the portion of cable that will run inside the housing will keep corrosion down and make the cable and housing interface smoother. This can sometimes reduce drag within the system and promote better shifting performance. Additional lubrication of the cables may be warranted in extremely wet conditions but in general should be avoided. Too much lubrication attracts dirt and debris, which has the potential to migrate into the housing, significantly degrading shifting performance.

STUDENT HANDS-ON:
Derailleur Cable Installation

Tools needed:
5 mm hex wrench
3/8" drive 5mm hex wrench
Torque wrench
Cable cutters
Chain tool

Step 1 - Confirm that the shifters are in their neutral position.

Step 2 – Preset the barrel adjuster position on the rear derailleur by turning the adjuster all the way in (clockwise) until it stops, then back out the adjuster (counterclockwise) 1/2 turn to 1 turn.

Step 3 – If there are additional barrel adjusters for the rear derailleur (possibly on the frame or at the shifter), turn them all the way in.

Step 4 – Preset the barrel adjuster position for the front derailleur in the same manner.

Step 5– Install new cables into the shifter. While holding the shift cable, actuate each shifter through the entire range to insure smooth operation of the shifter and cable.

Step 6 – Route cables through cable housing. If you choose to grease the cables, now is the time to do so. Route the cables through all cable stops and the correct mounting points on the derailleurs. Tighten the cable anchor bolt, but do not tighten to final torque yet.

Step 7 – Shift the derailleurs through the entire range several times to help seat cable end caps onto the housing, and the cable housing into the cable stops of the frame. Return shifters to the neutral position and re-check cable tension. If necessary, retighten rear derailleur cable and tighten cable anchor bolt to the manufacturer's torque specification. Then un-anchor front dreailleur cable and leave loose for now.

Step 8 – Trim rear derailleur cable to length and install cable end cap. An approximate length for rear cable is about 2".

Step 9 – Reinstall chain.

Crimp
Signature

REAR DERAILLEUR FINAL ADJUSTMENT AND FINE TUNING

There are two final adjustments needed to complete the rear derailleur system set up. You must adjust the indexing of the derailleur and set the body angle of the rear derailleur.

Adjusting the indexing will synchronize the shift system with all the corresponding cassette cogs and chainrings. The manufacturers have done most of the work by designing the index points in the shifters to precisely match the spacing of the cogs and chainrings of the cassette and crank. The mechanic synchronizes the system by fine tuning cable tension so that with the first click of the shifter the derailleur aligns perfectly with the second cog. After that, all the other clicks should line up the rear derailleur with the appropriate cog. The cable tension adjustment for the rear derailleur is performed by turning the barrel adjuster, which is generally located directly on the derailleur. Note that many newer mountain bike rear derailleurs do not have a barrel adjuster on them. For the front derailleurs and the mountain bike derailleurs mentioned above, use the barrel adjuster at the shift lever if applicable, or the one mounted on the frame.

The body angle adjustment screw (sometimes referred to as the "B tension" screw) is a fine tuning adjustment. Since there are many different gear ranges available for the rear cassette, the B tension screw allows you to fine tune the guide pulley relationship to the cassette cogs for a more precise shift. By setting the pulley within a range of 5 – 10 millimeters (this varies by manufacturer) from the largest cassette cog, this allows the chain the appropriate amount of room to shift, or derail from one cog to the next crisply.

On both Shimano and SRAM rear derailleurs the body angle screw is positioned behind the mounting bolt of the derailleur, and lines up with a tab built into the derailleur hanger on the frame. This design rotates the entire derailleur around the pivot of the mounting bolt. When turned clockwise, the body angle screw moves the guide pulley farther away from the cogs, lessening chain wrap and allowing excessive chain flex. When the screw is turned counter-clockwise, chain wrap is increased, but at the expense of shifting performance — the chain cannot move quickly from one cog to the next.

On Campagnolo rear derailleurs, the adjustment screw is located where the pulley cage attaches to the derailleur body. Only the cage rotates when the screw is adjusted, but the net effect is the same: the guide pulley moves in relation to the cassette cogs to fine tune shifting performance.

STUDENT HANDS-ON:

Rear Derailleur Index and Angle Adjustment

Tools needed:

- Screwdriver
- 5mm hex wrench

Step 1 – With the chain in the smallest chainring and the smallest cog, shift the rear derailleur one click/gear while pedaling. If the chain does not shift into the second position cog, or over-shifts into the third cog, stop pedaling. Move to the back of the bike and check the alignment of the guide pulley in relation to the second cog. Use the barrel adjuster to align the guide pulley with the second cog.

Step 2 – Shift through all remaining gears. Fine tune the cable tension with the barrel adjuster if necessary. If you are experiencing adjustment problems refer to the troubleshooting guide at the back of this chapter. Or begin again with step one.

Step 3 – Shift the system into the lowest gear combination (smallest chainring and the largest cassette cog). If you are having difficulty shifting into the largest cog, consult the troubleshooting guide at the back of this chapter.

Step 4 – Turn the cranks backwards and view the guide pulley relationship to the largest cassette cog. There should be a 5 – 10 millimeter gap between the guide pulley and the cog. If necessary, adjust the gap using the body angle screw.

FRONT DERAILLEUR LIMIT SCREW ADJUSTMENT

There are two limit screws on every front derailleur. Just like the rear derailleur, these screws limit the travel of the cage from moving too far inward or too far outward across the chainrings. Some may be marked with an H or L denoting high and low limits. However not all front derailleurs are marked. When referencing high and low gears on the front system, the high gear is the largest chainring and the low gear is the smallest chainring.

STUDENT HANDS-ON:

Final Front Derailleur Index Adjustment, Without Trim

Tools needed:

- Screwdriver
- 5mm hex wrench

Step 1 – Start with the chain running in the lowest gear combination. This will be the smallest chainring and largest cog. Sighting from above, check the gap between the inner cage plate and the chain. The gap should be .5 - 1 mm. Adjust the gap if necessary using the low limit screw.

Step 2 – While holding tension on the cable, attach it to the front derailleur. Make certain the cable is routed correctly before tightening the cable anchor bolt. Tighten to manufacturer's torque specification.

Step 3 – Shift the chain into the middle chainring. The shifter should be in the middle position. Use the barrel adjuster to set a gap of no more than 1 millimeter between the inner cage plate and the chain.

Step 4 – Shift the rear derailleur into the smallest cog. Check for interference with the outer cage plate of front derailleur and the chain. If interference is experienced, repeat step 3 or consult the troubleshooting guide at the back of this chapter.

Step 5 – With the chain in the largest chainring up front and the smallest cog in back, check the gap between outer cage plate and chain. The gap should be no more than 1 mm. You may need to apply pressure to the shifter to hold the derailleur against the high limit screw. Adjust the high limit screw if necessary to achieve the appropriate gap.

Step 6 – Shift through all the chainrings, making sure the chain shifts accurately without overshifting.

STUDENT HANDS-ON:

Final Derailleur System Adjustment

Step 1 – Shift through all possible gear combinations to ensure the entire system is functioning properly. Choose gears quickly and sporadically to simulate real riding conditions as much as possible in the classroom environment.

Step 2 – Have an instructor give your bicycle a final inspection. If it passes inspection, the instructor will sign off your Student Daily Checklist.

CAMPAGNOLO SHIFTER / DERAILLEUR SYSTEMS

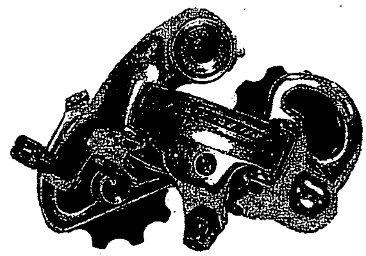

Fig. 18 - Campagnolo rear derailleur

There are a few characteristics of Campagnolo's derailleur systems worth noting. Campagnolo shifters are serviceable. With the 10 speed shifters a special insert can be installed to allow use with 9 and 8 speed Campagnolo systems. Campagnolo's 11-speed systems are not compatible with its 8, 9 or 10 speed systems. The front shifter incorporates a ratcheting mechanism, allowing for much greater trimming of the front derailleur with different gear combinations. This also allows one shifter to be used with both triple and double chainring configurations. Shifting action also differs from Shimano. Campagnolo's shifter uses the lever behind the brake lever as the spooling mechanism and the release button is up on the hood, towards the inboard side. Also the brake quick release mechanism is located at the brake lever instead of on the caliper. Another difference of a Campagnolo rear derailleur, as mentioned earlier in this chapter, is that the gap between the guide pulley and largest cog is set with an angle adjustment screw built into the derailleur pulley cage.

SRAM SHIFTER / DERAILLEUR SYSTEMS

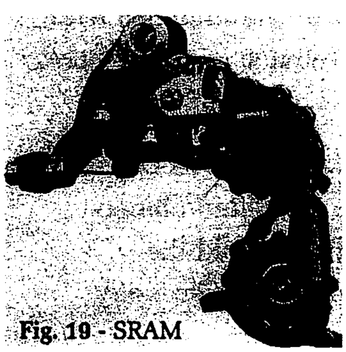

Fig. 19 - SRAM rear derailleur

SRAM produces both road and mountain bike drive trains. Just like Shimano and Campagnolo, they produce shifting systems and derailleurs which are proprietary in design. While they have some unique features, they are still approached in very much the same manner when it comes to adjustments. SRAM also manufactures a line of mountain bike shifters designed to be compatible with Shimano front and rear derailleurs. Within the road product line up, their "double tap"shifting mechanism is unique in that one lever is used to operate both the spooling of cable and the release of cable. This is also a proprietary design and will only function with SRAM derailleurs.

STUDENT HANDS-ON:

Cable Removal and Limit Screw Adjustment

Tools needed:
5 mm hex wrench
Cable cutters

Step 1 – Shift the system into the smallest chainring and smallest cog.

Step 2 – Disconnect the front and rear derailleur cables.

Step 3 – Remove cables from shift levers using manufacturer's recommended method. Remove cable housing from frame and inspect for damage, if it needs to be replaced do not discard yet.

Step 4 – Check initial set up of front derailleur. Be sure to check derailleur height and angle.

Step 5 – Check the high limit setting of the rear derailleur, adjust if necessary

Step 6 – Check the low limit setting of the rear derailleur, adjust if necessary.

Step 7 – Set initial barrel adjuster positions in the same manner as previous exercises.

STUDENT HANDS-ON:

Cable Installation

Tools needed:
5 mm hex wrench
Torque wrench
Cable cutter

Step 1 – Make sure the shifters are in their neutral position

Step 2 – Install new cables into the shifter. While holding the shift cable, run each shifter through the entire range to ensure smooth operation of the shifter and cable.

Step 3 - Route cables through the cable housing and through all cable stops. Route the cables through the correct mounting points on the derailleurs and tighten cable anchor bolt, but do not tighten to final torque yet.

Step 4 – Shift the derailleurs through the entire range several times to help seat the cable end caps onto the housing, and the cable housing into the cable stops of the frame. Return shifters/derailleurs to the neutral position and re-check cable tension. If necessary retighten cable tension and tighten the cable anchor bolt to manufacturer's torque specification.

STUDENT HANDS-ON:

Rear Derailleur Index and Angle Adjustment

Tools needed:
5 mm hex wrench
Screwdriver or 2.5mm hex wrench

Step 1 – Starting with the chain in the smallest chainring and the smallest cog, shift the rear derailleur one click, or position while pedaling. If the chain does not shift into the second position cog, or overshifts into the third cog, stop pedaling. Move to the back of the bike and check the alignment of the guide pulley in relation to the second cog. Use the barrel adjuster to align the guide pulley with the second cog.

Step 2 – Shift through all remaining gears. Fine tune the cable tension with the barrel adjuster if necessary. If you are experiencing adjustment problems refer to the troubleshooting guide at the back of this chapter. Or begin again with step 1.

Step 3 – Shift the system into the lowest gear combination. This will be the smallest chainring and the largest cassette cog. If you are having difficulty shifting into the largest cog, consult the troubleshooting guide at the back of this chapter.

Step 4 – Turn the cranks backwards and view the guide pulley relationship to the largest cassette cog. There should be a 5 – 10 millimeter gap between the guide pulley and the cog (top of the pulley teeth to top of the cog teeth). If necessary adjust the gap using the body angle screw.

STUDENT HANDS-ON:

Front Derailleur Index Adjustment, with Trim

Tools needed:
Screwdriver

Step 1 – Confirm proper front derailleur position.

Step 2 - Start with the chain running in the lowest gear combination. This will be the smallest chainring and largest cog. Sighting from above, check the gap between the inner cage plate and the chain. The gap should be no more than .5 -1 mm. Adjust the gap if necessary using the low limit screw.

Step 3a - Triple chainring system – There are two positions built into the shifter for the middle chainring. To properly set cable tension, make sure the shifter is in the innermost of the two positions. This is accomplished by shifting from the small chainring to the middle chainring, then with light pressure on the small inner release lever, shifting to the inner trim position. Using the barrel adjuster, set a gap no larger than .5 millimeters between the inner cage plate of the derailleur and the chain.

Step 3b - Double chainring system – There are two positions built into the shifter for the large chainring. To properly set cable tension, make sure the shifter is in the innermost of the two positions. This is accomplished by shifting to the large chainring, then with light pressure on the small inner release lever, shifting to the inner trim position. Using the barrel adjuster, set a gap no larger than .5 millimeters between the inner cage plate of the derailleur and the chain.

Step 4 – Shift rear derailleur into the smallest cog. Check for interference with the outer cage plate of front derailleur and the chain. If interference is experienced, use the trim feature of the shifting system. If this corrects the interference go on to step 5, if not, repeat step 3.

Step 5 – With the chain in the largest chainring and the smallest cog, check the gap between outer cage plate and chain. The gap should be no more than 1 mm. You may need to apply pressure to the shifter to hold the derailleur against the high limit screw. Adjust the high limit screw if necessary to achieve the appropriate gap.

Step 6 – Shift through all the chainrings, making sure the chain shifts accurately without overshifting.

STUDENT HANDS-ON:

Final Derailleur System Adjustment

Tools needed:
Cable cutters
Cable crimps

Step 1 – Shift through all possible gear combinations to ensure the entire system is functioning properly. Choose gears quickly and sporadically to simulate real riding conditions as much as possible in the classroom environment.

Step 2 – Trim cables and install end caps.

Step 3 – Have an instructor give your bicycle a final inspection. If it passes inspection the instructor will sign off your Student Daily Checklist.

REAR DERAILLEUR TROUBLESHOOTING GUIDE

If the shift lever clicks but the derailleur does not move chain to the next cog, there is not enough cable tension in the system to cause the derailleur to move the appropriate amount. Shift back to the first position, loosen the cable anchor bolt, pull the cable taught and re-tighten the cable anchor bolt to the appropriate torque value. Try shifting again to the second cog. If it now shifts, continue fine tuning the cable tension.

If the shift lever clicks and the derailleur moves the chain beyond the second cog, there is too much cable tension in the system, causing the derailleur to overshift. Shift back to the first position and try using the barrel adjuster to reduce the amount of cable tension to an appropriate amount. If this is not possible, you may need to loosen the cable anchor bolt and reset the barrel adjuster and the initial cable tension. Try shifting again to the second cog. If it now shifts, continue fine tuning cable tension.

If the chain shifts but makes noise while pedaling, the derailleur is possibly moving just slightly too far. Turn the barrel adjuster clockwise to center the guide pulley until the noise disappears. Continue to shift into additional cogs, adjusting the barrel adjuster as needed until all cogs shift quietly and responsively.

If the chain is not shifting into the largest cog, check the low limit screw. When properly adjusted, the guide pulley should be centered directly underneath the largest cog. Also double check to make sure that the shifter was in the neutral position before you anchored the shift cable to the derailleur. If not the detents in the system are not matching up, and you must move the shifter into the neutral position and re-anchor the cable.

If the chain is not shifting into the smallest cog, try turning the barrel adjuster clockwise (reducing tension within the system) a small amount. If the derailleur still does not move into the smallest cog, check the high limit screw. When adjusted properly, the guide pulley will line up directly underneath the cog. Also check to make sure there was not too much initial cable tension within the system when the cable was anchored to the derailleur.

If you are still having problems, check the following items.

- Derailleur hanger alignment
- Cable routing. Check all routing points: frame cable stops, cable guides and routing at the derailleur itself
- Chainline
- Compatibility between the shift lever, rear derailleur, cassette or freewheel, and chain
- Check for drag or friction within the cable and housing. Look for kinks, improper length housing, burrs in the ends of the housing and or end caps.
- Check for worn or damaged pivots in the derailleur

FRONT DERAILLEUR TROUBLESHOOTING

If the shift lever clicks but the chain does not shift, check initial cable tension within the system. If needed, loosen the cable anchor bolt, pull any excessive slack out of the cable and tighten the anchor bolt.

If the chain shifts, but the inner cage plate rubs on the chain after the shift, there is too much tension on the cable. Turn the barrel adjuster clockwise (reducing cable tension) until the rubbing just disappears.

If the chain shifts, but the outer cage plate rubs on the chain after the shift, there is too little tension on the cable. Turn the barrel adjuster counterclockwise (increasing cable tension) until the appropriate gap is reached between the inner cage plate and the chain.

If the chain is not shifting into the large chainring, first check the high limit screw for proper adjustment. Then check cable tension: more may be needed. You will need to shift back down to the inner chainring to determine if enough initial cable tension is there. Loosen cable anchor bolt and pull any excess slack out of the cable and reattach to the derailleur. Also check the cable routing and if there are any kinks in the cable. Try again, adjusting cable tension as needed.

If problems persist, check the following items

- Cable routing. Check all routing points: frame cable stops, cable guides and routing at the derailleur itself
- Chainline
- Compatibility between the shift lever, derailleur and chain
- Check for drag or friction within the cable and housing. Look for kinks, improper length housing, burrs in the ends of the housing and or end caps.
- Check for worn derailleur pivots

Electronic Shifting

Electronic shifting is not new to the bike industry. Various systems were introduced for road and comfort bike use over the last two decades. Suntour's BEAST (Browning Electronic Accushift Transmission) and Mavic's Zap and Mektronic systems are examples. However, those systems suffered from early reliability problems and never gained a foothold in the market. In 2008, Shimano introduced the Dura Ace Di2 (Digital Integrated Intelligence) electronic drivetrain. In 2011, Campagnolo introduced the EPS (Electronic Power Shift) electronic drivetrain. Both systems have made dramatic improvements in performance and reliability over the earlier designs mentioned above.

Shimano and Campagnolo electronic drivetrains are both wired systems. One of the advantages to using a wired system, as compared to a wireless system, is that a single power source can be used for the entire drivetrain. Another advantage is the lack of signal interference from other sources (power meters, heart rate monitors, power lines, etc.). The wiring harnesses are available for both internal and external routing, depending on frame requirements. The wires use waterproof connections at all junctions.

The battery that powers the system can be mounted in any number of locations on or inside the bike. The battery is proving to be very reliable, offering well over 1,000 miles between charging cycles. An external battery charge indicator can be viewed while on the bike. When the battery is getting low, the system begins to shift more slowly.

The primary shift lever function for both of the systems is very similar to their mechanical counterparts. Campagnolo uses a fixed brake lever in conjunction with a paddle, positioned behind the lever, to move the rear derailleur to a lower gear. A thumb lever on the inside of the hood to moves the rear derailleur to a higher gear. Shimano has moved to a fixed brake lever with 2 paddles behind it. The textured paddle closest to the brake lever moves the rear derailleur to a lower gear while the non-textured paddle closest to the handlebar moves the rear derailleur to a higher gear. Electronic drivetrains allow the end user the option of secondary, or satellite, shifters. These secondary shifters can be placed in a number of locations on the handlebar or aero bars for greater accessibility, allowing riders to shift without having to change hand positions. This is a big improvement over mechanical systems, especially in time trials or triathlons.

Rear derailleur indexing and adjustment is done with the system in adjustment mode. The adjustment mode is accessed using a button on a junction box that is a part of the wire harness (Shimano), or using the mode button on the control lever (Campagnolo). The set-up parameters are similar to a mechanical system. There are limit screws, indexing and body angle adjustments. The rear derailleur has a "crash saver" function that disengages the servo motor in the case of a crash. This allows the derailleur to move without damaging the motor or any of its parts.

The front derailleur utilizes one of the most interesting features of all, automatic trim. When the rider shifts the rear derailleur, its position is communicated to the front derailleur by the automatic trim function, which immediately adjusts the front derailleur's position so the drivetrain will operate without rubbing. The front derailleur cage is also narrower than its mechanical counterpart. The decrease in

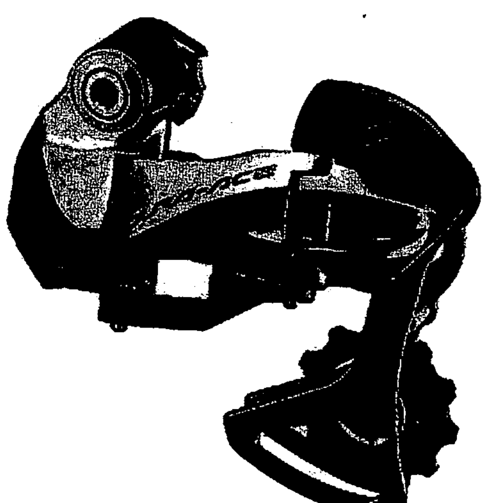

Fig. 20 - Electronic rear derailleurs: Shimano Dura Ace Di2 (left) and Campagnolo Super Record EPS (right)

width between the two cage plates has improved shifting performance due to greater stiffness.

ADDITIONAL READING ABOUT DERAILLEUR, SHIFT LEVERS, SHIFT CABLES and HOUSING

The purpose of this list is to provide some alternate sources of information to help you learn the material covered in class. There is no requirement to do any of this reading. Feel free to read as much or as little as you like.

Sutherland's Handbook for Bicycle Mechanics – 7th Edition, Chapter 7

The Dancing Chain: History and Development of the Derailleur Bicycle
By Frank Berto

Bicycle: The History
By David V. Herlihy

WEB RESOURCES:

Cyclingnews.com
Rear Derailleur Adjustment
www.cyclingnews.com/tech/fix/?id=rearmechadjust

Front Derailleur Adjustment
www.cyclingnews.com/tech/fix/?id=frontmech

Sheldon Brown
Derailer [sic] Adjustment
www.sheldonbrown.com/derailer-adjustment.html

Derailleur Collection
http://www.disraeligears.co.uk/Site/Home.html

Chapter 6

Brakes

Objectives:

- Identify and understand different brake types
- Service caliper and linear pull brakes
- Understand different types of disc brake systems
- Service and installation of mechanical and hydraulic brake systems

Brake systems on bicycles can be traced back to the 1860's. The "spoon brake" was possibly the earliest design, and was first seen on the "pedal velocipede" produced by Pierre Michaux in Paris. The basic principle involved a spoon-shaped piece of wood or metal that would depress on the tire — which on Michaux's machine was made of iron – using friction to slow the rotation of the wheel. Later, the spoon design was applied to machines that used pneumatic tires. While effective, the spoon brake quickly wore out the tire. During the same period, brake designs emerged that used the rim of the wheel or the hub as the braking surface. These did not cause wear on the tire, so they quickly became favored, and variations of them are still in use 150 years later.

Brakes may be more important than any other system of the bicycle. Proper brake setup and maintenance should be the primary safety concern of every mechanic, and the primary liability concern of shop managers and owners. Obviously, the consequences of a brake failure while riding could be catastrophic.

One potential source of brake failure is the incorrect tightening of an essential fastener during installation or repair. This is easily avoided by using proper torque values when initially setting up the brake or when performing routine maintenance, and by always doing a safety check on the brake system before returning the bike to the customer.

The second and perhaps most common cause of failure comes from lack of routine maintenance. Normal wear and tear degrades brake performance, especially in harsh riding conditions: braking surfaces (pads, rotors, rims) wear down, cables fray or corrode, springs fatigue, pivot lubrication dries out, air or moisture gets into hydraulic systems, and dirt migrates into cable housing. Therefore, a mechanic should routinely inspect the braking system of a bike taken in for repair, even if the reason for the repair is unrelated to the brakes. If the mechanic finds that components of the braking system are worn, the customer should be informed and those components should be replaced to ensure that the brake system is operating safely before it's returned to the rider.

Brake systems are composed of four main components - the levers, the cables and housing, (or in the case of hydraulic systems, hoses, fittings and fluid), the braking surface (rim, hubshell or rotor), and the brake mechanisms themselves. All of these components must work together in order to get the best braking performance out of the system. This means that all components must be compatible with each other and with the frame or fork on which they are installed. Compatibility issues are an important part of brake system setup and will be discussed in more detail later in this chapter.

Types of Brakes

Contemporary bicycle brakes can be divided into two major categories and several sub-categories. The two major categories are hub brakes and rim brakes.

Hub Brakes

Hub brakes directly use the hub as part of the braking system. This means all or part of the brake is built into the hub, or in the case of disc brakes, to a rotor attached to the hub. Braking force is applied at the center of the wheel.

Hub brakes have some advantages over rim brakes. First, hub braking mechanisms are often internal, so the brake is protected from the elements. This means performance is less affected by wet and muddy conditions, and the brake requires less maintenance. Hub brakes are also unaffected by an out of true wheel, because no part of the brake makes contact with the rim.

Hub brakes have some disadvantages, however. They usually require much more material in their design than rim brakes, which makes them heavier. In the case of cheaper internal hub brakes (like coaster brakes), heat build-up under prolonged braking can cause the brakes to fade severely.

There are four distinct types of hub brakes used on bicycles: coaster brakes, drum brakes, roller brakes and disc brakes.

Coaster Brakes

Coaster brakes are found on bicycles with single drive cogs, such as cruisers, kids' bikes, and internally geared hubs (figure 1). The brake is activated by pedaling backward, which causes an internal clutch to engage, forcing a pair of brake shoes against the interior walls of the hub shell. Coaster brakes are very simple, durable, and require very little maintenance, making them the ideal choice for utility and commuting bicycles. Coaster brakes are also more suitable for children's bikes because children may not have enough hand strength to activate standard brake levers.

Overhauling and service of a coaster brake is a very simple process, but one which is done infrequently in many bike shops, thus the procedures for the various models of hubs are quite often forgotten by even the best mechanic. The Sixth Edition of the Sutherland's Handbook for Bicycle Mechanics has a section devoted to newer coaster brake hubs. Sutherland's also published a coaster brake-specific manual that is out of print, but may be worth finding on the used market if the shop plans to offer coaster brake service.

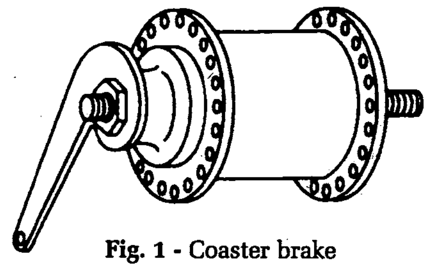

Fig. 1 - Coaster brake

When servicing a coaster brake-equipped bike it is important to consider the rest of the drivetrain (chain, bottom bracket, etc.) as essential parts of the brake system.

Drum Brakes

Drum brakes (figure 2) are similar in design to the brakes found on motorcycles and automobiles. Like a coaster brake, the hub is a major part of the drum brake's assembly, as an internal mechanism forces a pair of brake shoes against the inside wall of the hub. Unlike the coaster brake, a drum brake is actuated using a brake lever and cable instead of back pressure on the crankset. Some benefits of the drum brake design are low maintenance and good performance in adverse conditions.

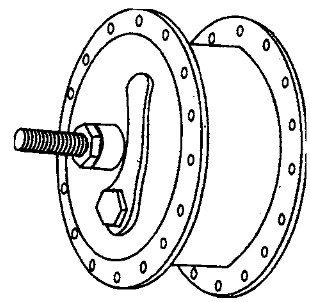

Fig. 2- Drum brake

Drum brake shoes are larger than most bicycle brake shoes, so more surface area is engaged, plus the pads are actuated using a pivoted cam mechanism, which increases their mechanical advantage. For this reason, drum brakes are quite often found on tandems and other heavy-duty applications that require a large amount of stopping power.

Roller Brakes

The roller brake is a Shimano product used on some of their internally geared hubs. The design is similar to a drum brake. It mounts directly to the hub and is held in place by a locknut. The brake is activated by a cable attached to a disc that rotates around the axle. The disc has ramped notches that support several roller bearings. When the brake is actuated, each roller bearing pushes out on a pad that contacts the brake body, creating the friction needed to slow the bike. Some models of roller brakes have cooling fins to dissipate the heat generated during braking.

Disc Brakes

Disc brake technology has also been borrowed from the motorcycle industry, and has been available in the bicycle industry since the mid 1970's (figure 3). However, those early systems were heavy and performed poorly, so disc brakes were slow to gain market share. However, advances in materials and engineering have resulted in systems that are lighter, stronger and perform extremely well. The benefits of disc brakes are their stopping power, performance in wet conditions, and excellent modulation. Disc brakes will be discussed in more detail later in this chapter.

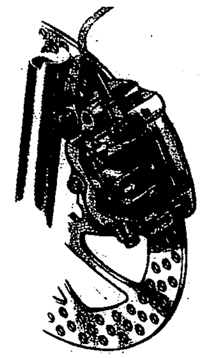

Fig. 3 - Disc brake

RIM BRAKES

Rim brakes are the most common type of bicycle brake. They can be inexpensive, lightweight, and perform well when properly installed and adjusted. Rim brakes are unique in that the brake components are only part of the brake system. The rim of the wheel is also an integral part of the system. Therefore, rim material, design, and condition can affect the braking performance tremendously.

As a general rule, the harder the rim surface, the poorer the braking performance. This is because it is difficult for a brake shoe to grab and hold a hard, smooth surface. For example, braking performance is generally poor on bicycles equipped with chrome-plated steel rims, especially when the rims are wet. Aluminum alloy rims typically perform better. The softer and more porous surface allows for better pad adhesion to the rim, which transfers braking power more efficiently.

Caliper Brakes

Rim caliper brakes typically mount on the frame or fork by a single bolt. When the brake lever actuates the cable, the caliper arms move inward, engaging the brake shoes with the rim's braking surface. There are two types of caliper brakes used on bicycles – center-pull and side-pull. The main difference between the two is how the cable routes and attaches to the caliper. The location of the cable anchor is either in the center (center-pull) or at the side (side-pull, figure 4) of the caliper.

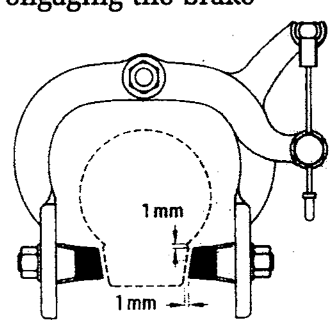

Fig.4- Rim caliper brake

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Center-pull and side-pull brakes are typically found on road bicycles. Both have been in use for decades, but the side pull design is more common. This is due to its simple cable routing and cleaner appearance.

A variation of the side-pull, known as the dual pivot (figure 5), has become the common caliper design on road bikes. Dual pivot brakes have one pivot located in the center of the caliper and a second pivot located on one of the brake arms. This design can carry a minor weight penalty over a single pivot side-pull, but provides more braking power due to its increased leverage.

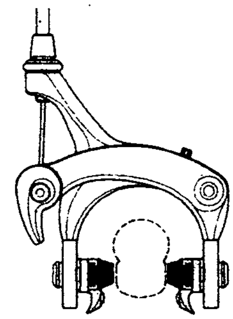

Fig. 5 - Dual pivot caliper brake

Cantilever Brakes

Cantilever brakes consist of two independent arms, which pivot around their own mounting post (also called a cantilever brake boss). The bosses are 8mm in diameter and typically mount on the fork legs and seat stays. They are different from caliper brakes in that the two arms attach to the frame independently of each other and are actuated using a cable, which connects the two arms together. This cable is called the transverse cable, straddle cable or link wire. Cantilevers are most often found on older mountain bikes, cyclocross bikes, and many touring bikes, because this design provides increased clearance for wider tires, fenders (and mud) and is compatible with road levers.

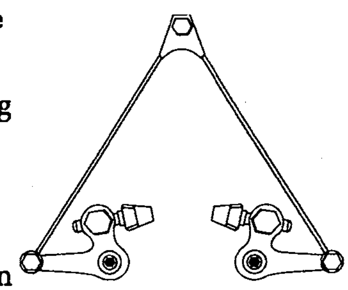

Fig. 6 - Mafac cantilever brake

Early cantilever designs can be traced back to the 1920's and 1930's. Cantilever designs have changed dramatically over the last two decades. In the 1960's a French company named Mafac utilized the design for touring and cyclocross bikes.

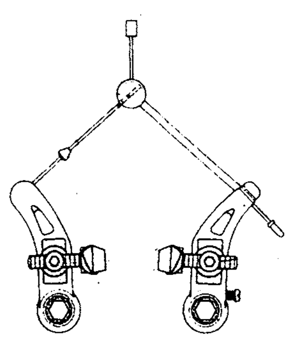

Fig. 7 - Low profile cantilever brake

The original Mafac brake had a very wide profile (figure 6). Its arms extended outward so they were horizontal to the ground. This design had two problems - one was the outward protrusion quite often caused the heel of the rider to hit the brake when pedaling. The biggest problem, though, was the lack of mechanical leverage inherent in the design. The angle that the transverse cable extended from the arms was not conducive to good braking power so a large amount of braking energy was being lost (more on that issue later in this chapter). In the early 1980's, the profile of the cantilever arms became more vertical. Now most cantilevers are considered to be this low profile design (see figure 7).

Cantilever brakes are still being used, predominantly on touring and cyclocross bikes. The linear pull brake (figure 8) has replaced the conventional cantilever on mountain bikes because of its braking power. Linear pull brakes are similar to cantilevers, but their arms are longer and almost vertical. Unlike cantilevers, where the housing stop is mounted above the brake, linear pulls are designed with the housing stop on one arm, and the brake cable attaches straight across to an anchor bolt on the other arm. The longer arms characteristic of this design give linear pulls a greater mechanical advantage over standard cantilever brakes.

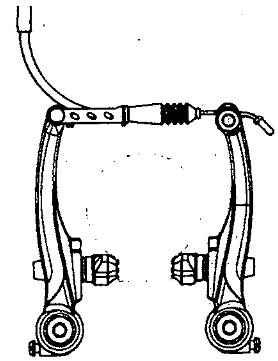

Fig. 8 - Linear pull brake

U-brake and Roller Cam Rim Brakes

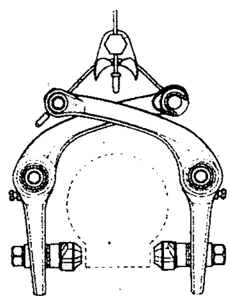

Fig. 9 - U-brake

Both of these brake designs were initially developed for mountain bikes and BMX bikes. However, both of these brake systems use mounting bosses that are 8.9 mm in diameter. They are mounted in different positions on the frame and fork, making them completely incompatible with traditional cantilever or linear pull brakes.

The U-brake (figure 9) looks similar to a center-pull caliper. While U-brakes have been abandoned in favor of linear pull brakes and disc brakes on mountain bikes, BMX bikes still frequently utilize them due to their compact design and good braking power.

The roller cam (figure 10) utilizes a long-arm cantilever design combined with a cam and pulley system, which increases the mechanical advantage of the brake as the lever is squeezed. Roller cam brakes were found for a few years on both mountain and BMX bikes, but the design has been abandoned. These brakes had excellent stopping power, but were difficult to set up and made wheel changes challenging.

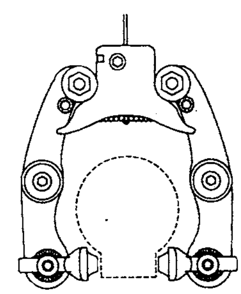

Fig. 10 - Roller cam

25mm brake pull leverage normal
37mm for V brakes

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RIM BRAKE CALIPER DESIGN, COMPATIBILITY, & SERVICE

A caliper brake is simply two arms that act as levers that revolve around one or two pivot points. Each arm rotates smoothly around its pivot because there are bushings or bearings between them. The pivot is usually adjustable so play between the two arms can be fine tuned, very much like a bearing adjustment. Most caliper arms also have vertical slots that allow adjustment of the shoes up or down to compensate for subtle variations in rim design. Both caliper arms are held outward, away from the rim, by a return spring.

Rim Brake Caliper Compatibility

There are several areas of caliper brake compatibility that bike mechanics have to consider. Cables and housing must be the right type and cut to the right lengths, brake shoe material must be appropriate to the rim material, and the length of the caliper arms must allow the shoes to line up properly with the side walls of the rim. Cables, housing and brake shoes will be discussed later in this chapter.

All caliper brakes attach to the frame and fork using the hole in the center of the brake bridge or fork crown. However, the distance from the mounting hole to the rim can vary, depending on the intended use and design of the bicycle. The height of the hole above the rim affects how much tire clearance the bicycle will have. The farther the hole is from the wheel, the more tire clearance is available. Therefore a road touring bike may have a fairly high brake bridge to allow clearance for larger tires and fenders, whereas a racing bike may have very little clearance.

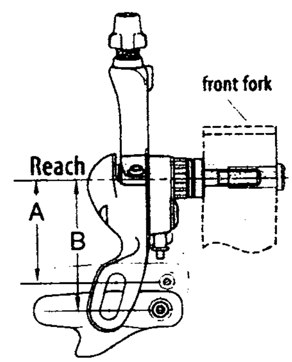

Fig. 11 - Measuring brake reach

Correspondingly, different caliper brake models may have different length arms. This is typically referred to as the brake's reach. Brake reach compatibility can easily be measured on the frame and brake caliper. On the frame or fork, it is a measurement from the center of the mounting hole to the center of the sidewall of the rim. (see figure 12 on page 6-8). On the brake caliper, reach is measured from the center of the fixing bolt to the top and bottom of the shoe slot of the arm. The brake reach of the arm is measured in two points to give a range of adjustment capability. Referring to figure 11, you will see the shortest reach the brake is capable of achieving (the highest shoe setting) is called dimension A, the longest reach is called dimension B. Note on the drawing that both dimensions are measured to the center of the shoe bolt. As long as our frame or fork measurement is between dimension A and B, our frame or fork and brake calipers are compatible with each other.

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STUDENT HANDS-ON:

Rim Brake Caliper Removal and Brake Reach Measurement

Tools needed:
5 and 6 mm hex wrenches Cable cutter Vernier caliper

Step 1 - Select a road bike with rim caliper brakes.

Step 2 - Check the current condition of the system by actuating the levers a few times.

Step 3 - Remove both the front and rear brake cables by cutting the cable above the anchor bolt. Remove the cable and housing from the brake levers.

Step 4 - Remove the front and rear brake calipers.

Step 5 - Measure the reach compatibility of the frame and fork using the vernier caliper. Measure from the center of the mounting hole in the fork crown or brake bridge to the center of the braking surface of the rim (see figure 12). Write down your answer below.

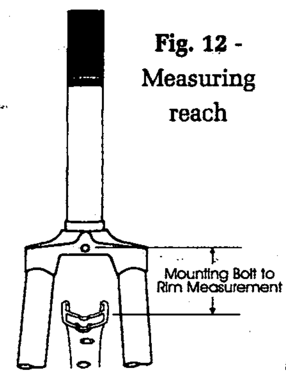


Fig. 12 - Measuring reach

Frame and Fork Brake Reach = 49mm / 42mm

Step 6 - Remove the brake shoes from both arms.

Step 7 – Slide a 6mm hex wrench through both of the pad slots and slide it all the way up the slots.

It is important to note that the brake arms should be held parallel in order to get an accurate measurement.

Step 8- Measure dimension A from the bottom of the mounting bolt to the bottom of the hex wrench. Since mounting bolts are 6mm and brake shoe bolts are the same diameter as the hex wrench, we will get the same measurement as measuring center to center. Write down your answer below.

Caliper Dimension A= 43mm \ 42mm

Step 9 - Measure dimension B of the brake caliper (figure 11).

To get dimension B, slide the hex wrench to the bottom of the slots. Again, measure from the bottom of the hex wrench to the bottom of the mounting bolt. Write down your answer below.

Caliper Dimension B= 52mm / 50mm

Rim Brake Caliper Installation

When installing rim brake calipers onto a frame or fork, care must be taken to ensure the interface between the caliper and frame provides sufficient support for the caliper to be securely tightened. If the contours of the two surfaces do not match, the brake may rotate under load, causing misalignment of the pads to the rim. Special washers are available to make these uneven surfaces mate properly. Always use the correct washer when installing caliper brakes to ensure that the caliper will stay tight, even under severe braking forces (see figure 13).

Fig. 13 -Caliper mounting washers

It is important to note that if you install a washer, the effective length of the mounting bolt will be reduced an amount equal to the thickness of the washer. In order to accommodate any differences, recessed nuts of different lengths are available.

Nearly all modern caliper brakes come with some type of thread locking compound pre-installed on the fixing bolt. The U.S. Consumer Product Safety Commission (as well as other governmental standards authorities around the world) requires this for the original installation of the caliper. Older caliper brakes may use nuts with a section of nylon in the threads that compress against the bolt, acting as a thread locking agent by exerting pressure on the threads.

Modern caliper brakes are installed using a recessed 5 mm hex socket nut. The brake bridge or fork crown mounting hole has been countersunk so the nut's head is flush with the edge of the hole.

Most manufacturers require that a minimum of 6 threads be engaged when using the recessed nut. When installing a caliper, the mechanic should always observe the manufacturer's specifications for minimum thread engagement.

Caliper Brake Pivot Adjustment

Over the life of the brake, normal operation will cause wear in the pivots. The gap between the rotating arms can loosen because the bushings that separate the arms wear. At this point, the pivots can be readjusted. Most pivot adjustments are performed like a standard bearing adjustment. The adjustment procedure depends on the caliper's pivot design.

1. Double-Nut Type Pivot Adjustment - One pivot design uses two nuts butted up against each other on the face of the caliper. The outside one is the locknut, and the inside one is the adjustable nut. To perform this adjustment, loosen the locknut with the appropriate sized wrench while holding the adjustable nut with a thin brake wrench. Once the locknut is broken free, turn the adjustable nut clockwise until the play just barely disappears. Tighten the locknut and check the adjustment. The final result should be arms that pivot easily and have a minimal amount of play.

2. Single-Nut Type Pivot Adjustment -This type can be identified by a single set of wrench flats or a screwdriver slot on the outside face of the caliper mounting bolt. This is the head of the center bolt, which also acts as the adjusting bolt. The locknut for this type is between the caliper and the frame or fork. While holding a wrench or screwdriver on the bolt head, loosen the locknut. Turn the bolt head until the desired adjustment is obtained, tighten the lock nut and check the adjustment.

3. Dual-Pivot Type Adjustment – On dual pivot calipers there are two adjustable pivots: one in the center and one on the right side. Some models use ball bearings instead of bushings, which smooth the operation of the pivot. Both pivots are adjusted in a similar manner as the single-nut type. They both may have a lock nut and/or possibly an additional set screw. Loosen the set screws and/or locknuts before making any adjustments.

Brake Shoe Design and Materials

Brake shoes come in a variety of designs and materials, and most caliper brake shoes are interchangeable. However, manufacturers offer specialty shoes in different materials and hardnesses designed for a variety of rim surfaces. The correct pad compound for the rim's braking surface is necessary for proper performance.

As a general rule, softer shoes perform best when used on standard aluminum alloy rims. But the brake's mechanical leverage also affects the brake's modulation. For example, soft shoes deform more when making contact with the rim, providing a broader contact patch. This is good for some brakes, but inappropriate for some of the more powerful designs like dual-pivot and linear pull brakes. Because of these brakes' increased leverage, they can easily distort a soft brake pad, which can cause a more "grabby" feel and unpredictable modulation. Higher leverage brakes perform best with a slightly harder compound.

Many of the special shoes available for ceramic rims actually contain abrasives in the compound for better adhesion against the rim. These shoes should always be used with ceramic rims because the harder, more porous texture of these rims will quickly wear down the softer compounds used in standard brake shoes. All rims are subject to excessive heat buildup caused by friction between the rim and shoe. But ceramic rims do not conduct heat nearly as much as standard rims, so the shoe absorbs most of the heat. This can melt and glaze over the surface of standard shoes and decrease their performance and service life. Therefore, ceramic-coated rims also do best with a ceramic specific shoe compound.

Carbon rims also require specific brake pad compounds. Many carbon-specific pads are cork or formulations containing cork, but the pad compound recommendations vary by manufacturer. It is important to consult the rim manufacturer's specifications to ensure that you are utilizing the correct pad for a carbon rim.

Rim Brake Shoe Installation and Adjustment

When installing the brake shoes, the shoes must properly align with the rim. If the shoe is too high it will rub the tire. If it is too low, the shoe will dive off the bottom of the rim, and the edge of the rim will carve a step into the brake pad. In either case, braking performance will suffer. The ideally-adjusted shoe will hit the rim squarely, at the right height, and following the profile of the rim. There are six adjustments that must be considered when aligning the shoes to the rim.

1. Shoe Height - The vertical slot on caliper arms allows the shoe to be positioned at a variety of heights. Ideally the center of the shoe should contact the center of the rim's braking surface. This allows a "buffer zone" at the top and bottom of the rim, creating a safety margin if the wheel loses roundness or gets dented.

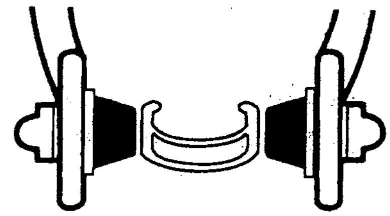


Fig. 14 -Pads should contact braking surface squarely.

2. Shoe Angle - The shoe should rest evenly across the contour of the rim's outline. Some shoes are directional. They may have a contoured outline similar to the rim, or they may have directional arrows on them. When installed, the arrows should always be facing the front of the bicycle. All four corners of the shoe should be equal distance from the rim's edges.

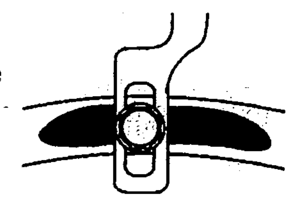


Fig. 15 -Pads should follow rim's profile.

3. Shoe Interface - The interface is the angle at which the face of the shoe makes contact with the rim. This adjustment is not possible on many caliper brakes (although it is with many cantilever and linear pull designs), but at least we can make sure the design of the shoe face is compatible with the angle of the rim sidewall. This may only be a problem with rim sidewalls that have a steeper or shallower angle than the norm. In severe mismatches, the shoe can be modified using coarse emery cloth or a file by laying the abrasive on a table and rubbing the shoe against it at the appropriate angle.

4. Shoe Toe-In - Brakes squeal due to loose pivots, flex in the brake arms or bike frame, surface contamination, etc. These factors can cause the brake shoe to vibrate on the surface of the rim, creating the squeal. In cases like this, toe-in is necessary to eliminate, or at least reduce, the problem. Shoes should be toed in so the leading edge of the shoe makes contact with the rim before the trailing edge. This can be checked by softly squeezing the brake arms inward until the leading edge barely makes contact. The trailing edge should have a gap of .5 to 1.5 millimeters (see figure 16). Too much toe-in will reduce the amount of shoe surface making contact with the rim, thus reducing braking power.

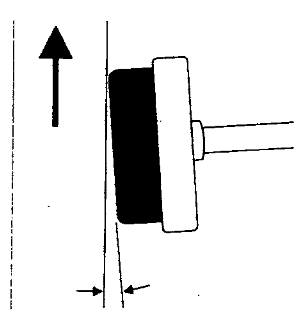


Fig. 16 -Brake shoe toe-in (.5-1.5mm)

Too little toe-in, or reverse toe-in, will contribute to squeal. Though the shoes and arms will start out at an angle, they will twist and become flat against the rim. This twisting motion increases stiffness in the arms and reduces the potential for squeal.

There are other conditions that can lead to brake squeal. The hardness of the rim and shoe can combine to cause the shoe to slide and vibrate. Anodizing on the rim side-wall creates a layer of surface hardness. Eventually, through normal riding, this hard-ness is worn through, the squeal disappears, and braking performance actually improves. Many mechanics accelerate this process by placing a piece of Scotchbrite or emery cloth between the shoe and rim while turning the wheel until the anodizing is worn through. Brake shoes can also be sanded in this manner to break through the glazed surface that many new shoes have from the molding process. Sanding brake shoes is also part of routine brake service. Under no circumstances should the brakes be toed-in by bending the brake arms. This may cause the arms to fail and will void the manufacturer's warranty.

5. Shoe to Rim Clearance - The last two adjustments can only be performed once the cable is installed. When the cable is in place, the final distance between the shoe and rim should be 1 to 2 millimeters per side. This will be discussed in more detail later in this chapter.

6. Shoe Centering - This is the last adjustment on the caliper once the cable is installed. Both shoes must be an equal distance from the rim. This too will be discussed in more detail later in this chapter.

Once the shoe is positioned, the shoe mounting bolt should be tightened. The final torque should be achieved gradually. Tighten the fixing nut in 3 or 4 stages, stopping between each stage to make sure the shoe has not moved. Tightening too fast in the wrong position may distort the shoe hardware in such a way it may become difficult or impossible to readjust the shoe a second time to the correct position.

Brake Cables and Housing Compatibility

Most bicycles use brake cable that is 1.6 mm in diameter. The housing for 1.6 mm brake cable is 5 mm in diameter. Brake cable housing is flat wound (see figure 16 on page 5-18) and available both lined and unlined. Lined, flat wound housing is preferred due to its stiffness and smoothness.

Brake cables are available with two kinds of heads, based on the brake lever in which they will be installed — upright (mountain bike) levers or drop bar (road bike) levers. The two head types can be viewed in figure 17. "Universal" cables have a mountain head at one end and a road head at the other end. The mechanic chooses the appropriate head for the brake lever, cutting off the other.

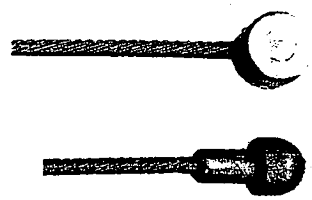


Fig. 17 -Top: cable for flat bar levers. Bottom: cable for drop bar levers.

Like derailleur cables, brake cables are available in extra smooth die-drawn versions and coated versions. These cables are more expensive than standard ones but reduce friction in the system considerably. For proper performance, the brake housing must be able to rest inside the frame's cable stops. In some cases, you may be able to use a different size than was intended by installing special step-down ferrules on the housing ends (figure 18).

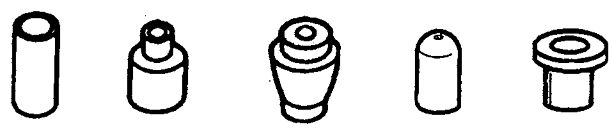


Fig. 18 -Housing ferrules

The length of the housing can greatly affect the performance of the system. Housing that is too short will cause binding, especially when the front wheel is turned. Housing that is too long will create increased drag and poor modulation. So what constitutes the right length? Housing should be kept as short as possible while allowing the cable to move smoothly. A good rule of thumb is to size the housing to provide a smooth arc from stop to stop (see figure 19). When determining proper housing length, make sure to turn the handlebars to ensure that the housing does not bind.

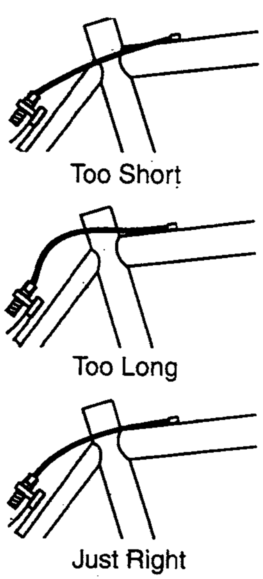


Fig. 19 -Proper cable housing length provides a smooth arc from stop to stop.

Caliper Brake Levers and Cable Installation

Caliper brakes are usually used with drop bar levers, although they are also used with flat bar road levers on commuter bikes (which is much more common in the European and Asian markets). The lever is attached to the handlebar by a clamping band that tightens around the bar. Road bike lever clamp diameters come in two sizes - one for steel handlebars and one for aluminum alloy handlebars. Steel drop handlebar clamp diameters vary, but most are under 23 mm. Most road bike handlebars are made of aluminum alloy or carbon fiber, and levers designed to clamp onto them have an adjustable clamp range of 23.8 - 24.2 mm, which is enough to adjust itself to fit any standard handlebar. Most tighten using a single fixing bolt recessed under the hood. When installing any brake lever, the clamp should be tightened to the manufacturer's torque specification In some cases this may be dictated by the handlebar manufacturer.

The cable end attaches to a rotating barrel near the pivot of the lever. The barrel is countersunk on one side so the head will fit down inside and be flush with the outside of the barrel. This is to keep the head from snagging on the interior walls of the lever and to keep the cable properly aligned with the exit hole.

As with derailleur cables (see chapter 5), if grease is going to be used, apply it only to the sections of brake cable that will run inside the housing.

There are two types of cable anchoring systems used on caliper brakes. One is a simple eyebolt. This is a bolt with a hole drilled through the center that the cable passes through. The most common, however, is a grooved washer. When anchoring cables into a grooved washer, you must ensure the cable is resting in the groove or the cable may slip when actuated, causing the brake to fail.

STUDENT HANDS-ON:

Rim Brake Caliper Installation and Adjustment

Tools needed:

- 3mm, 4mm, and 5mm hex wrenches
- 4mm and 5mm hex bits
- Micrometer torque wrench
- Cable cutters

Step 1 – Install brake pads into caliper, paying close attention to the orientation of the pad carriers and concave washer. The guide fins on the carrier should be pointed down and the opening in the carrier must face toward the back of the bike. Lightly tighten the pad mounting bolts.

Step 2 - Check the pivot adjustment and readjust if necessary. Make sure that there is no excessive movement between the two arms. Set the centering screw to neutral.

Step 3 – Install the calipers on to the frame or fork using the appropriate washers to improve the interface if necessary. Using your hand, compress the brake caliper so that the pads contact the rim and tighten the caliper mounting bolt to the manufacturer's torque specification.

Step 4– Check the housing for appropriate length. Make any corrections that may be necessary. The handlebar should be able to rotate through its entire range without the housing limiting the rotation.

Step 5– Install the cable into the lever, making sure that the cable head is seated correctly in the counter-sunk hole in the pivot barrel. If lubrication is applied to the cable, only apply it to the section of cable that will be inside the housing. Install any necessary ferrules.

Step 6 – Turn barrel adjuster clockwise until it stops. Route the cable through the barrel adjuster and the cable anchor bolt assembly. Make sure that the cable is routed through the cable anchor bolt assembly following the manufactured groove.

Step 7 – Use your hand to compress the brake caliper so that the pads contact the rim. Lightly pull on the cable and tighten the cable anchor bolt to the manufacturer's torque specification. Cycle the brake lever a few times to seat the cable and housing in place.

Step 8 – Turn the barrel adjuster counter-clockwise until the brake pads contact the rim. Adjust the brake pads to meet the following criteria:

> **Height**- The center of the shoe should contact the center of the braking track of the rim.
>
> **Angle**- The shoe should be centered following the contour of the rim with all four corners of the pads equal distance from the rim edges.
>
> **Interface**- The pads should meet the rim squarely with the entire pad in contact with the rim.

Step 9 – Tighten the brake pad mounting bolt to the manufacturer's torque specification. Be certain that during this step the pads do not rotate.

Step 10 – Turn the barrel adjuster clockwise until it stops. Check that travel is consistent for both levers. Balance if needed.

Step 11 – Perform a failure test by firmly squeezing the brake lever up to ten times, making note of any slippage. Correct any changes that occur. Double check the shoe to rim interface.

Step 12 – Inspect the gap between the pads and rim on each side of the wheel. If centering corrections are necessary do so using the method that is appropriate to the model of brake being installed.

Step 13 – Cut the cable leaving two inches extended beyond the cable anchor bolt. Install a cable end cap.

Step 14 – Have an instructor check your bicycle for final inspection. If it passes the inspection, the instructor will sign your Student Daily Checklist.

Cantilever and Linear Pull Brakes

Mounting Boss Compatibility

Cantilever and linear pull type brakes are universally mounted onto a boss that is 8mm in diameter. This makes them all compatible as long as the bosses are mounted in the correct position. Unfortunately, this is not always the case. The location of the bosses on a given frame and the design of the rims can vary.

Linear Pull Cantilever Mounting

22.2 - Flat
24.0 - Road
Bar Dia

Most linear pull cantilevers have their own pivot built into the body, so the brake itself does not actually rotate around the boss. This makes most of the boss problems associated with older cantilevers less relevant. A slightly bent or mushroomed boss will still allow the brake to fit over the post and rotate freely.

Spring Hole Choices

Cantilever brake bosses generally have either one or three holes drilled into the base for mounting the brake return spring. Cantilever bosses that have three holes allow the brake's return spring rate to be adjusted. The higher the hole, the higher the spring rate. Generally the middle hole is considered to be a neutral setting and suitable for most applications. Because most linear pull and current cantilever designs utilize a mechanism that pivots on the brake arm itself rather than the brake boss, and because the spring rate has an external adjustment, linear pull brakes should be mounted with the pin mounted in the center hole.

Cantilever Boss Width and Axle Center to Boss Center

Earlier generation cantilever brakes utilize brake pads that have non-threaded mounting posts. This gives them a wide range of adjustment making them somewhat unaffected by boss width. Linear pull brakes and contemporary cantilevers, on the other hand, use threaded posts with a series of concave and convex washers. This limits the adjustment to only a few millimeters either way. Because of this limitation, the cantilever boss width dimension is more critical. Most manufacturers specify a cantilever boss width dimension of 75-85 millimeters when using rim dimensions of 19- 33 millimeters in width.

Linear pull 22-26mm cable pull
Canti 12-13mm

Measuring cantilever brake reach is similar to measuring caliper brake reach. The obvious difference is the method in which the system is mounted to the frame and how this relates to the required measurements. Brake reach measurements for caliper brake equipped frames and forks are taken from the center of the mounting hole to the center of the braking surface on the rim. Similarly, brake reach measurements for cantilever brake equipped frames and forks are taken from the center of the brake boss to the center of the braking surface on the rim. Unlike caliper brakes, however, cantilever brakes are not available in varying amounts of reach to accommodate different mounting bolt center to rim center distances.

Small differences in reach may exist between manufacturers and models, but these variables are rarely published. Large discrepancies between cantilever brake reach and mounting bolt to rim measurements probably reflect poor frame design or an incompatible wheel size. The best way to verify what problem you may be facing is to take an axle center to boss center measurement. Using common brake post mounting guidelines you should be able to decipher what wheel size the frame was designed for or if the boss placement is incorrect.

STUDENT HANDS-ON:

Removing Linear Pull Brakes

Tools needed:
5mm hex wrench
Cable cutters
Vernier caliper

Step 1 - Select a bicycle with linear pull brakes.

Step 2 - Disconnect the cable linkages and remove both wheels.

Step 3 - Remove both the front and rear brake cables. Cut the cable between the brake noodle and the anchor bolt.

Step 4 - Loosen and remove the brake arm mounting bolts. Remove both front and rear brake arms.

Step 5 - Remove the brake shoes.

Step 6 - Measure the distance between the boss centers. Record your findings below.

Center to center boss width = 80-8 81

Squared? Toe in?

Jack the Bike Man

133

STUDENT HANDS-ON:

Linear Pull Installation and Adjustment

Tools needed:

- 5 mm hex wrench
- 5 mm hex bit
- Micrometer torque wrench
- Cable cutters

Step 1 - Clean and inspect the brake boss for contamination or damage.

Step 2- Apply a thin layer of grease to the outside of the cantilever post. Be careful not to get any grease inside the threaded hole.

Step 3 Install each brake pad onto the appropriate brake arm, ensuring proper orientation if applicable (see figure 20 for proper washer orientation). Lightly tighten the pad mounting bolts.

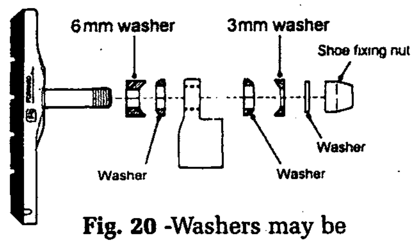


Fig. 20 -Washers may be reversed to correct linear pull arm orientation.

Step 4 - Install each linear pull brake arm onto the appropriate boss, placing the spring pin in the middle hole.

Step 5 - Install the mounting bolts (and washers, if any) and tighten to the manufacturer's torque specification.

Step 6- Rotate each brake arm through its normal arc to make sure it pivots freely without drag.

Step 7 - Reinstall the wheel, ensuring it is properly centered and seated in the dropouts.

Step 8 - Inspect the housing for proper length and smooth routing. The handlebar should be able to rotate through its entire range without the housing limiting the rotation. Correct if necessary.

Step 9 - Install the cable into the brake lever and lubricate if appropriate. Route the cable through the housing, any necessary ferrules and the brake noodle. Thread the barrel adjuster all the way in (clockwise).

Step 10 – Check the cable and housing by holding the end of the cable and pulling the brake lever.

Step 11 – Place the noodle in the brake arm carrier and route the cable through the cable anchor bolt assembly. Make sure that the cable is routed following the manufactured groove. Pull the cable through so each pad contacts the rim. Lightly anchor the cable.

Step 12 – Turn the barrel adjuster out (counter-clockwise) until the brake pads are held firmly to the rim. Adjust the brake pads to meet the following criteria:

> Height - The center of the pads should contact the center of the braking track of the rim.
>
> Angle – The pads should be centered following the contour of the rim with all four corners of the pads equal distance from the rim edges.
>
> Interface – The pads should meet the rim squarely.
>
> Toe-in – With the front portion of the pads contacting the rim, there should be a .5 – 1.5 mm gap at the rear of the pad.

Step 13 – Carefully tighten the brake pad mounting bolt to the manufacturer's torque specification. Be certain that during this step the pads do not rotate out of position.

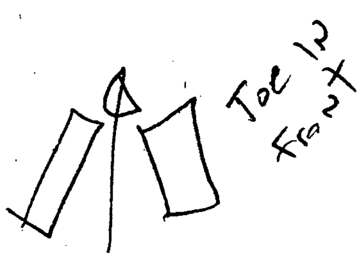
Step 14 – Turn the barrel adjuster in (clockwise) until it stops then back it out one full turn (counter-clockwise). Loosen the cable anchor bolt and adjust the cable tension so that there is a 2-3mm combined gap between the shoes and the rim. Tighten the cable anchor bolt to the manufacturer's torque specifications. Check that the travel is consistent for both levers and balance if needed.

Step 15 - Adjust the final centering of the brakes. If equal distance is not present, readjust by turning the spring adjusting screw on the side of the cantilever arm. Turning clockwise increases the spring tension and moves the arm outward, turning counter-clockwise decreases the spring tension and moves the arm inward. Linear pull brakes have spring adjusting screws on both sides.

Step 16 - Perform a failure test by firmly squeezing the brake lever up to ten times.Check the pad to rim position and clearance and correct any problems.

Step 17 – Cut the cable and install a cable end cap.

Step 18 - Have an instructor check your linear pull brake installation and adjustment for final inspection. If it passes the inspection, the instructor will sign your Student Daily Checklist.



Brake Lever Design and Compatibility

Brake levers have several features that allow them to adjust to different applications. Many flat bar brake levers are equipped with reach adjusters that allow customizing the lever to hand size. Most mountain levers have barrel adjusters that allow later tightening of the brake cable as the shoes wear down. Many levers are equipped with return springs in the lever, which provide a lighter feel and assist the system in releasing the brakes when the lever is let go. Flat bar lever clamp diameters are universally compatible with all mountain bike handlebars at 22.2 mm.

As mentioned earlier in this chapter, brake systems are composed of four main components - the levers, the cables and housing (or hydraulic lines), the braking surface and the brake caliper. It should be obvious that a lever designed to function in a hydraulic system will not work with a cable activated caliper, but unfortunately, other brake compatibility issues are not always this simple to recognize. Brake levers have been designed with varying amounts of leverage to correspond with the requirements of different brake caliper types.

Leverage is directly related to the amount of cable that is pulled by a given brake lever. Simply put, the more leverage that a brake lever has the less cable it pulls. And the more cable a brake lever pulls, the less leverage it has. This is important to note when attempting to mix caliper and lever types. Many combinations will appear to function adequately while the bike is in the repair stand, but when in service may produce unpredictable or even dangerous brake performance.

An example of a potentially unsafe combination is a standard road bike drop lever with a linear pull brake - a configuration that might be tried on a touring or cyclocross bike. The linear pull brake requires a lever that can pull 22-26 mm of cable. A standard cantilever brake lever only pulls between 12 and 19 mm of cable. Drop bar levers pull even less cable and therefore have a relatively large amount of leverage. The combination of road levers and linear pull brakes results in an excessive amount of power coupled with a lack of pad travel. To remedy this poor performance, some aftermarket products are available that are designed to increase cable pull and can improve the performance of incompatible components. Dia-Compe manufactures a special road-style brake lever designed to be used with linear pull brakes, for example.

Many mountain bike brake levers have adjustable leverage which can regulate how much braking power can be transmitted to the rim. This adjustment actually increases or decreases the distance between the cable end and the lever pivot. The smaller the distance, the greater the leverage.

Disc Brakes

Disc brakes have become commonplace on today's mountain bikes, and their use on cyclocross, commuting and touring bikes is increasing. The first benefit to a disc brake system is that the majority of its parts are better protected from contamination than a rim brake. This is because the rotor and caliper are mounted near the center of the wheel, keeping them out of the mud and dirt. Disc brakes also offer more consistent stopping power than a rim brake due to a harder braking surface and more durable brake pad materials. The braking surface of the rotor is most often made of stainless steel and the brake pads are constructed of either a resin/ organic or metallic compound. The stainless steel rotor is much more durable than the aluminum rim that serves as the braking surface for a rim brake. Rubber is the most common rim brake pad compound and is less tolerant of abrasive contamination than disc brake pad compounds.

The two disc brake systems currently being used are the cable-actuated type and the hydraulic type. The cable disc brake is very similar to a standard brake system where the brake is activated by a lever pulling on a cable. The cable moves an arm on the caliper that pushes the brake pad against the rotor. The hydraulic disc brake uses a brake lever that contains a piston that pushes fluid through a hose attached to the caliper. The fluid pushes against single or multiple slave pistons in the caliper that then moves the brake pads against the rotor. In hydraulic brake systems, all of the brake components are designed to work specifically with each other and are not compatible with other systems. Different brands of brakes use different types of fluid. Some systems use a proprietary mineral oil, while others use DOT 3, DOT 4, or DOT 5.1 brake fluid.

Care must be taken to make sure that all components are compatible, or the brake system will not function correctly. For example, when using a disc brake system, the bicycle's frame and fork must have mounting tabs that are compatible with the caliper. There have been several caliper mounting configurations used in the past. Currently the most common mounting systems used are the 74 mm post mount (figure 21) and the 51mm ISO (international standard) mount (figure 22). An adapter may be required to mount the brake caliper to the frame or fork.

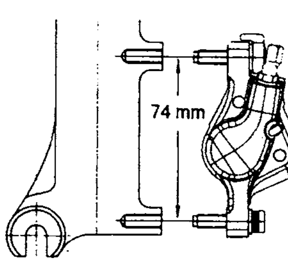


Fig. 21 -74 mm post mount

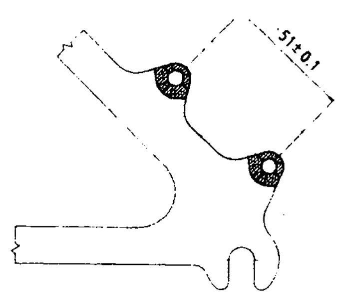


Fig. 22 -51 mm ISO disc brake mount

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Rotors

Currently there are two rotor mounting systems in use The first type, called ISO or 6 bolt (figure 23), mounts the rotor to the flange of a disc-compatible hub using six bolts. The bolt circle diameter for this design is 44 mm. The second system, called "Centerlock" (figure 24), is a splined design that is similar to a cassette rear hub where the rotor fits onto a splined section on the hub. A lock ring is used to secure the rotor to the hub. The two systems are not compatible, so the hub used must be specifically designed to accommodate the type of rotor being used. However, adapters are available to use a 6-bolt rotor on a centerlock hub.

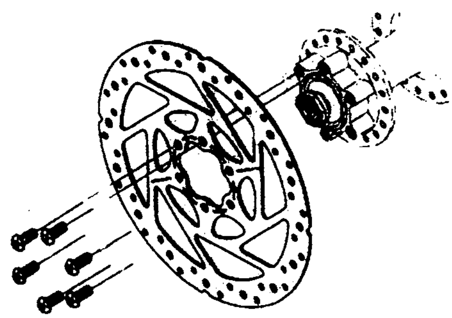

Fig. 23-ISO 6 bolt rotor mount

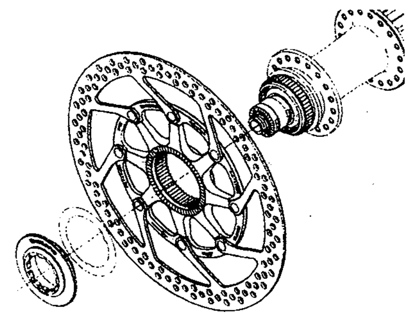

Fig. 24- Shimano Centerlock rotor mount

Rotor (disc) size, and shape vary from brand to brand and model to model. There are several factors that must be considered when a manufacturer designs a rotor. First, the rotor must be able to withstand very high temperatures without warping or getting soft. If the rotor's surface softens as it heats up, the brakes feel sticky and lose their modulation. It must also handle rapid temperature changes without warping. If the rotor warps it will rub the pads and create unwanted drag. The second factor is corrosion. Because the rotor is the braking surface it would be impractical to paint or apply any surface finish, so the rotor material itself must have good corrosion resistance. Third, the cost of manufacturing is always a factor.

Currently stainless steel is the most popular material for rotors, because it resists heat and corrosion, and is relatively inexpensive. Its major drawback is weight. Aluminum alloy is also being used because of its lighter weight, but aluminum's drawbacks are that it wears quickly and displays inconsistent performance in varied conditions. There has been some experimentation with carbon fiber and ceramics as well. Some rotor designs use an alloy spider in the center, with a stainless steel braking surface at the edge. This design reduces weight and stiffens up the rotor.

The diameter of the rotor affects the leverage the brakes have on the wheel: the larger the rotor, the greater the leverage. Rotors range in diameter from 140 mm to 203 mm. This should be considered when choosing a brake system. Since the front wheel has most of the stopping power, the front rotor is often larger than the rear. This helps to balance the brake system. The wrong combination of front and rear rotors may cause the brakes to lock up or reduce modulation. Some frame and fork manufacturers have size limitations on rotors because of the amount of force they put on the frame or fork caliper mounting tabs. Always consult the manufacturer before changing rotor size.

The shape or cut of a rotor is important as well. Rotors are often manufactured with holes or cutouts in the braking surface. These serve several purposes. They not only reduce the weight of the rotor, but they also help in cooling, help clean the brake pads and allow gases to escape during braking, increasing braking performance.

Disc Brake Calipers

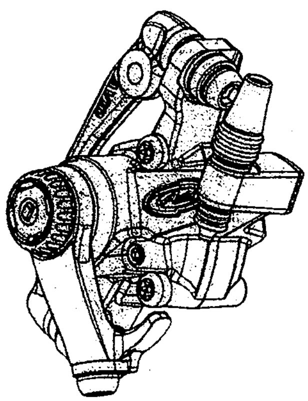

Fig. 25 - Disc brake caliper

There are several different caliper designs being used. The most basic is a single piston type. In this design, only one pad moves when the brake lever is pulled. The rotor must flex enough to contact the other, stationary pad. This design is used in mechanical and low cost hydraulic disc brakes

Most hydraulic disc brakes use a system where there are slave pistons on both sides of the rotor. This type may utilize two pistons (twin piston design), four (a quad piston design) and even six pistons. The benefit of the quad piston design is that the brake pads can be larger and better supported, which in turn increases the braking force on the rotor.

Levers, Hoses, Cables and Housing

The brake levers used on a mechanical disc brake system are standard cable-type levers. Mountain bike systems are designed to use the same lever as linear pull brakes (Figure 26) . Road or cyclocross systems, where drop bars are used, have a different caliper that is designed specifically to be used with road-style brake levers. The cables and housing used on a mechanical system are standard. It is recommended to use flat wound housing and die drawn cables for best performance.

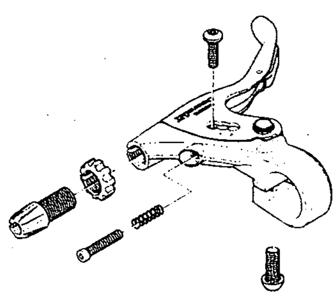

Fig. 26-Lever for mechanical disc brake

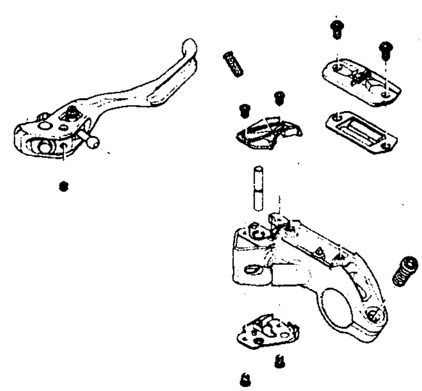

Fig. 27-Lever for hydraulic disc brake

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Hydraulic brake levers serve as both the brake lever and the housing for the master cylinder (figure 27). They are completely incompatible with cable disc systems, and should only be used with hydraulic systems from the same manufacturer.

STUDENT HANDS-ON:

AVID Mechanical Disc Brake Installation

Tools needed:

- 2.5mm and 5mm hex wrenches
- 3/8" drive 5mm hex bit
- Micrometer torque wrench
- Cable cutters

Step 1 - Select an appropriate mountain bike and clamp it in the repair stand. Disconnect the front brake cable by cutting the cable above the cable anchor bolt. Remove the cable from the housing and then from the brake lever. Remove the front wheel.

Step 2 - Loosen the brake caliper body positioning bolts.

Step 3 - Turn both pad adjustment knobs counter-clockwise until they stop. Turn inboard (stationary) pad adjustment knob clockwise 1 and 3/4 turns.

Step 4 - Place the front wheel in the fork and tighten the skewer. If the rotor will not fit between the pads, back off the inside pad adjustment until the rotor just fits.

Step 5 - Turn the outboard adjustment knob clockwise until the pads firmly squeeze the rotor and the actuating arm is immobile. The front wheel should not rotate freely at this point. Tighten the caliper positioning bolts to the manufacturer's specifications.

Step 6 - Run the brake cable through the anchor bolt on the actuating arm. Pull out all slack and tighten the cable anchor bolt to the manufacturer's torque specifications.

Step 7 - Turn each pad adjustment knob counter-clockwise 2 to 3 clicks, or until the rotor just clears the pads. Perform a failure test by firmly squeezing the brake lever a few times, paying close attention to any slippage that occurs. Correct any problems.

Step 8 – Trim cable so that no more than 19 mm is extended past the cable anchor bolt. Install a cable end cap.

Step 9 - Have an instructor check your brake installation and adjustment. If it passes inspection, the instructor will sign your Student Daily Checklist. After the instructor has checked your work, remove the disc brake caliper, back out the pad adjustment knobs, and turn it in to your instructor.

BLEEDING HYDRAULIC BRAKES

Problems can occur in a hydraulic brake system when air, dirt or other substances contaminate the fluid. This can happen if any of the components gets damaged or connections loosen up. Air in the system causes the brakes to feel spongy or fail entirely. Other contaminants may expand or even boil the brake fluid, or break down the seals or other internal components. "Bleeding"is the process used to remove the air or other contaminants from the brake system. The system should be bled if you notice excessive brake lever travel, the brakes feel spongy, or if the brakes "fade" or slowly lose their effectiveness.

The fluids used in a hydraulic brake system are designed to resist expanding or boiling when subjected to the heat created by braking. The two fluids typically used in bicycle disc brake systems are DOT brake fluid and mineral oil (although this synthetic oil is completely different from the mineral oil sold in pharmacies). It is important to note that brake fluids are not interchangeable. A system designed to work with mineral oil will be damaged if DOT brake fluid is substituted, and vice versa. When bleeding a hydraulic system using DOT brake fluid, avoid getting the fluid on your skin or on the bicycle (especially painted surfaces or the brake pads) as it is caustic. It is recommended to use safety glasses and gloves for this procedure, and you will be required to do so in class.

Prior to bleeding, the brake components should be inspected for any damage and for any visible fluid that would indicate a leak. Also be sure to check that all connections are tight. If damage is found, it should be repaired before bleeding the system. If there are no visible signs of damage or leaks and all the connections are tight, bleeding is the next step.

Metallic Pad Hotter

Organic Resin Lighter Duty

Less than 1/2 of Pad Left Replace then

Brand/Model/Year Specific

STUDENT HANDS-ON:

Shimano Funnel Bleed

Tools needed:

- Shimano Mineral Oil/Shimano Funnel Bleed Kit
- Plastic tire lever
- 6,7 and 8 mm combination wrenches
- 2, 3, 4 and 5 mm hex wrenches
- Small phillips screwdriver
- Bladed screwdriver
- Torque wrench
- Needle nose pliers
- Shimano bleed spacer (yellow)
- Shimano travel spacer (orange)
- Protective gloves
- Safety glasses
- Shop rags
- Isopropyl alcohol

Step 1 – Select a mountain bike and place it in the repair stand.

Step 2 – Prepare the Shimano Funnel bleed kit by drawing 40ml of Shimano Mineral Oil into the syringe.

Step 3 – Remove the wheel from the bike. Remove the pad axle using the appropriate tool. Remove the pads and pad spring and place them away from any possible contamination source.

Step 4 – Using a cotton swab that is saturated with rubbing alcohol clean around the exposed pistons in the caliper body. Reset the pistons using a tire lever. They should sit flush with the caliper body. Install the yellow bleed spacer.

Step 5 – Identify the current position of the brake lever on the handlebar and mark its location with a pencil or piece of tape. Loosen the brake lever clamp bolt and rotate the lever so that it is at a 45 degree angle.

Step 6 – Remove the bleed screw and O-ring from the lever. Thread the funnel in to the lever bleed port. Do not install the oil stopper.

Step 7 – Remove the bleed nipple cover from the caliper bleed nipple. Place the closed end of a 7mm combo wrench on to the bleed nipple. Install the hose from the syringe on to the bleed nipple. Open the bleed port by turning the bleed nipple 1/8 – ¼ of a turn counter-clockwise.

Step 8 – Once the bleed nipple has been opened, push on the syringe plunger to add oil to the system. Continue adding oil until the oil that is exiting the system into the funnel is free of air bubbles.

Step 9 – Temporarily close the bleed nipple. Remove the syringe and install the catch bottle and hose to the bleed nipple. Using the remaining oil in the syringe, top off the oil in the funnel at the lever.

Step 10 – Open the bleed nipple 1/8 – ¼ of a turn. Oil and air will begin to flow from the bleed nipple into the hose. This will assist in getting any air trapped in the caliper out. Gently tapping the line and caliper with the handle of a screwdriver can help dislodge air bubbles. Keep in mind that the fluid level in the funnel will be dropping throughout this step. Make sure that there is always fluid visible in the funnel.

Step 11 – Once air bubbles stop coming out of the caliper bleed nipple temporarily close the bleed nipple. Pull the brake lever to the handlebar and hold. Open and close the bleed nipple in rapid succession once. Release the blake lever. Repeat this 2 to 3 times. Tighten bleed nipple to the manufacturer's torque specification. Remove the hose and catch bottle from the bleed nipple. Clean the caliper with rubbing alcohol.

Step 12 – Pull and release the brake lever, looking for air bubbles to exit the bleed port at the lever into the oil funnel. Once the bubbles stop appearing pull the lever toward the bar. At this point the lever should have a stiff feel.

Step 13 – Loosen the brake lever clamp bolt and rotate the lever to a starting position that is parallel to the ground. Rotate the lever up 30 degrees. Pull and release the brake lever to help remove any remaining bubbles in the lever reservoir. Next, rotate the lever down 30 degrees past the parallel position and repeat the pull and release sequence. If air bubbles continue to appear repeat this step until they stop.

Step 14 – Once air bubbles have stopped appearing in the funnel, place the oil stopper, O-ring side down, in the funnel. Remove the funnel from the lever and install the lever bleed screw. Tighten to the manufacturer's recommended torque specification.

Step 15 – Clean up the lever with isopropyl alcohol and reposition the lever to its original orientation. Tighten the brake lever clamp bolt to the manufacturer's recommended torque specification.

Step 16 – Remove the yellow bleed spacer. Install the pad, spring and pad combo into the caliper. Install the pad axle. If threaded, tighten to the manufacturer's recommended torque specification. Install the orange travel spacer. Pull and release the brake a few times with the travel spacer in place to allow the piston to move out evenly.

Step 17 – Loosen the caliper mounting bolts. Remove the orange travel spacer. *Install* the wheel in to the frame/fork. Pull and hold the brake lever and tighten the caliper mounting bolts equally and incrementally to the manufacturer's recommended torque specification.

Step 18 – When you are finished, have an instructor check your work. If it passes inspection the instructor will sign off your Student Daily checklist.

STUDENT HANDS-ON:

AVID Juicy Hydraulic Disc Brake System Bleed

Tools needed:

- T-10 Torx wrench
- Avid disc brake bleed kit
- 2, 4, 5 mm hex wrenches
- Torque wrench
- Safety glasses
- Protective gloves
- Shop rags
- Isopropyl alcohol

This procedure can be used for all SRAM/Avid disc brakes. To achieve the best service possible use of the Avid Disc Brake Bleed Kit is recommended. The following procedure assumes that the bleed kit is being used.

Step 1- Place the bicycle into the repair stand, clamping by the seatpost. Remove the wheel from the bicycle.

Step 2 - Determine the correct method to remove the brake pads and spacer clip. Remove the pads and spacer clip, taking care not to touch the braking surface of the pads. Place the pads away from any possible contaminants. Install the bleed block.

Step 3 - Fill one syringe 1/2 full with Avid Hi-Performance DOT Fluid and the other syringe 1/4 full. Hold both syringes tip up and remove any air bubbles.

Step 4 - De-gas the DOT fluid by closing the syringe clamp and then applying a modest back pressure to the plunger. This creates a mild vacuum and you will see small air bubbles form. Tap the syringe to free the bubbles, then push them from the syringe. Note: it is impossible to remove all air bubbles from syringe.

Rider customizability

Step 5 - If the lever is equipped with the pad contact adjust feature, turn the pad contact knob all the way to the "out" position (opposite the direction the arrow points). For models equipped with a barrel style pad contact adjuster, turn the pad contact barrel all the way to the "out" position (opposite the direction the arrow points). Then you will need to rotate the barrel back just enough so that the bleed port is pointed straight up.

Step 6 - Use a T-10 Torx wrench to remove the caliper bleed port plug from the center of the banjo bolt. Make sure the fluid in the 1/2 full syringe is pushed all the way to the tip (no air gap), then install syringe into the caliper bleed port.

Step 7 - Remove the lever bleed port screw (Torx T-10). Make sure there is no air in the lever syringe, then thread it into the lever.

Step 8 - Hold the caliper and lever syringes upright. Open the caliper and lever syringe clamp, and gradually push fluid from the caliper syringe through the system until the caliper syringe is 1/4 full and the lever syringe is 1/2 full.

Step 9 - Close the lever syringe hose clamp. Pull the brake lever all the way back to the handlebar and hold it there until instructed to release it later. Or hold it to the handlebar with a toe strap or rubber band..

Step 10 - Gently pull back on the caliper syringe plunger to create a light vacuum. This should draw air bubbles out of the caliper. Then push fluid back into the caliper. Repeat this process until you stop seeing large air bubbles leave the caliper.

Step 11 - Once you stop seeing large air bubbles leave the caliper, apply a small amount of pressure to the caliper syringe and slowly let that fluid pressure extend the brake lever you've been holding with your finger. Note: if you used something to hold the lever to the handlebar you will need to release it first, but keep the lever pulled in with your finger.

Step 12 - Remove the syringe at the caliper and replace the caliper bleed port screw. Clean the DOT fluid from the caliper using a rag and soapy water or alcohol.

Step 13 - Open the syringe clamp at the lever.

Step 14 - Gently pull out on the lever syringe to create a mild vacuum, which should draw air bubbles out of the lever. Gently push in on the syringe to push fluid back into the lever. Squeeze and release the brake lever ten times, allowing it to snap back to its starting position after each squeeze. Repeat until large bubbles stop appearing.

Step 15 - Apply a small amount of pressure on the syringe plunger then remove syringe and replace bleed port screw. Clean the DOT fluid from the lever using a rag and soapy water or alcohol.

Step 16 - Remove the bleed block from the caliper. Select the appropriate pads and pad spring, place the spring between the pads. Compress the pad/spring/pad combo and load them into the caliper. Press firmly on the bottom of the pads until they are fully seated in the caliper.

Step 17 - Install the wheel, making sure it is squarely and completely seated in the dropouts. Pull lever and check for caliper to rotor alignment.

Step 18 - If re-alignment is necessary begin by loosening the caliper positioning bolts. With the bolts loose pull the brake lever to the bar and hold. Tighten the caliper positioning bolts equally and incrementally to manufacturers recommended torque specification. Check alignment.

Step 19 - Have an instructor check your brake. If it passes inspection, the instructor will sign it off on your Student Daily Checklist.

ADDITIONAL READING ABOUT BRAKES

The purpose of this list is to provide some alternate sources to help you learn the material covered in class. There is no requirement to do any of this reading. Read as little, or as much as you would like.

Sutherland's Handbook for Bicycle Mechanics (7th Ed):

Brakes, Pages 1 - 1 through 1 - 47

Bicycling Science, 3rd Ed:

Braking, Pages 237 - 261

Web Resources:

Disc Brakes:

http://bike.shimano.com

http://www.hayesdiscbrake.com/support

http://www.hopetech.com/page.aspx?itemid=spg131

http://www.magura.com/en/

http://sram.com/en/service/avid/

Caliper Brakes

cyclingnews.com: "Adjusting dual pivot caliper brakes"

http://www.cyclingnews.com/tech/fix/?id=caliperbrakes

Cantilever Brakes:

http://www.sheldonbrown.com/cantilever-geometry.html

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CHAPTER 6 APPENDIX

Standard Cantilever Mounting

Standard cantilevers are mounted to the boss by a 6 x 1 mm bolt. Most bolt heads are designed for a 5 mm or 6 mm hex wrench. Before removing a cantilever, rotate the brake on its boss to make sure it pivots freely. After removing the bolt, you will notice that the end of the boss will protrude beyond the brake arm a small amount. This is to allow the bolt or washer to tighten down against the boss and not the cantilever arm itself. If the cantilever arm binds and does not move freely, it is an indication that the boss or the washer are damaged.

Because the cantilever boss protrudes beyond the arm a small amount, overtightening the mounting bolt can cause the end of the boss to flare outward or become "mush-roomed". This can cause the arm to bind. Fortunately, this can be easily remedied by filing the end of the boss until the arm moves freely. Another more accurate way to alleviate this problem is by using the Bicycle Research Brake Boss Mill. This tool has a guide bolt that threads into the boss and guides a hand mill which cuts the boss to a precise 8mm diameter.

A bent boss can be a more serious problem, and more difficult to repair. A bent boss can be identified by holding a small straight edge (such as a machinists scale) along the length of the boss and looking for any gaps. A bent boss can sometimes be repaired by using the Bicycle Research Brake Boss Mill. In many cases, however the boss will need to be replaced. Fortunately, many cantilever bosses are designed with a base that is permanently attached to the frame, and a replaceable post that threads into the base. It is important to use some type of thread locking compound when replacing this post. If the boss doesn't have a replaceable post, you will need the services of a competent frame builder to replace the entire boss.

Another potential cause of cantilever binding is a damaged or distorted fixing bolt washer. The washer that rests against the end of the cantilever boss can become distorted due to overtightening, causing the washer to make contact with the cantilever arm.

STANDARD CANTILEVER BRAKE SET-UP

Standard Cantilever Brake Design

As mentioned earlier in this chapter, cantilever brakes have gone through several changes since they were first introduced. Most standard cantilevers are referred to as low profile. The angles of the arms have gotten steeper and protrude less to the outside.

The shoe assemblies have gotten simpler and easier to set up using radiused surfaces. The transverse and main cable linkages have become more integrated. Today, they are more powerful than ever and require very little maintenance. In simple terms, the cantilever is merely a lever rotating around a fulcrum with a shoe attached. Standard cantilever arms contain a bushing. Like all bushings, they are made of a smooth material, like brass, and are designed to rotate around the bosses with minimal drag. Each side of the cantilever has an independent return spring. As with all brakes the return spring holds the arms in an outward position away from the rim. The springs are different for left and right side brakes and are usually color-coded. Most right side springs are silver and most left side springs are gold, but a few manufacturers in the past have strayed from this designation. If reinstalled into the wrong arms, the cantilevers will remind you of that fact by holding the brake shoes permanently against the rim rather than away from it. Cantilever return springs are not interchangeable among manufacturers, or often among models from the same manufacturer.

Most cantilevers have some sort of spring adjustment device. This is identifiable by a screw on the side of the arm, or on some models, by a set of wrench flats on the front or rear of the arm. This feature is usually only found on one side, though some designs, including linear pull brakes, may have it on both sides. The end of the spring rests against a movable plate activated by the adjustment screw or nut. Turning the screw clockwise increases the tension by winding up the spring, and turning the spring counterclockwise decreases the tension. Using the adjusting screw makes it easy to center the brakes by equalizing the spring tension on each side. For brakes with a spring adjusting screw on both sides, they can also be used for increasing the overall return rate of the brakes.

Cantilever Brake Reach

Like caliper brakes, cantilever shoes have a range of adjustability for different frames and rims. Brake reach compatibility on a frame or fork is measured in a similar manner as caliper brakes. It is a measurement from the center of the brake boss mounting bolt to the center of the braking surface of the rim (see figure 28). It may be more accurate, however, to measure from the lower edge of the boss to the center of the rim and then subtract 4 millimeters (half the boss width). This is the preferred method whenever trying to measure to the somewhat nebulous center of a hole. The measurement is the same for all cantilever designs.

The cantilever arm is also measured in a similar manner. Measure from the center of the mounting hole in the brake boss to the center of the shoe post in the highest position, and then measure the same for the shoe in the lowest position. The shortest dimension, to the bottom of the slot, is referred to as Dimension A. The longest dimension, to the top of the slot, is Dimension B (see figure 29). Again, as with caliper brakes, as long as the frame or fork measurement is between dimension A and B, the frame or fork and cantilevers are compatible with each other.

HOW TO:

Measuring Cantilever Brake Reach

Step 1 - Check to be certain the wheels are properly centered and seated in the frame.

Step 2 - Measure the mounting bolt to rim measurement of the frame and fork using vernier calipers. Measure from the center of the cantilever brake boss to the center of the sidewall of the rim (see figure 28). Write down your answer below.

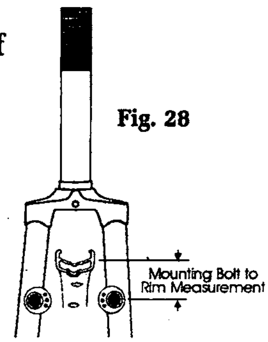

Fig. 28

Mounting bolt to rim measurement = _______________

Step 3 - Measure dimension A of the cantilever arm. Measure from the center of the mounting hole in the arm to the bottom of the caliper arm slot. Since you need to actually measure to the center of the shoe post (which is 6 mm in diameter), add 3mm to get the final measurement. Write down your answer below.

Cantilever arm Dimension A=______________

Step 4 - Measure dimension B of the cantilever arm. The most accurate method is to measure the length of the slot, add that to your initial measurement taken in dimension A (before you added the 3 mm), then subtract 3mm to get the final measurement (for an accurate measurement to the center of the bolt). Write down your answer below.

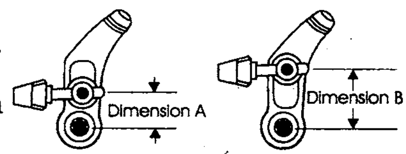

Fig. 29

Cantilever arm Dimension B= __________________

Standard Cantilever

Transverse Cable Geometry

The transverse cable found on standard cantilever brakes exists because the vertical movement of the main cable must somehow be converted to a horizontal movement in order to pull the cantilever arms inward. One of the biggest challenges in setting up cantilevers is the positioning of the transverse cable. The angle and length of the cable can have a dramatic affect on braking performance.

Some systems allow complete freedom when adjusting the angle and length. Others, such as the Shimano link wire system, have a built-in predetermined angle and length (figure 30). There are many factors that determine the best transverse cable setup for

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any given brake system, such as the type of cantilever arm design (wide profile, narrow profile, etc.), the type of brake levers used (drop bar, mountain bike, etc.) and even the distance between the brake bosses.

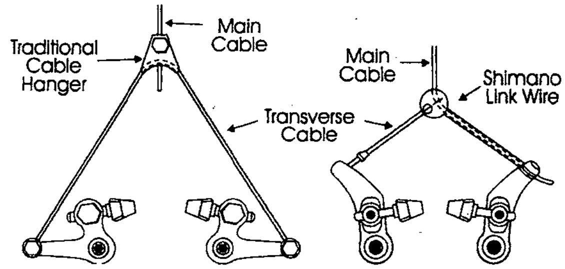


Fig. 30-Different arm designs require different transverse cable geometry.

In simple terms, the closer you can get the transverse cable to a 90 degree angle relative to the cantilever arm pivot, the more braking power is transmitted into the rim (see figure 31). If the force is not transmitted at 90 degrees, part of the energy gets wasted in pulling up on the brake boss.

Setting Up Transverse Cable Geometry for Cantilevers with Link Wire Systems

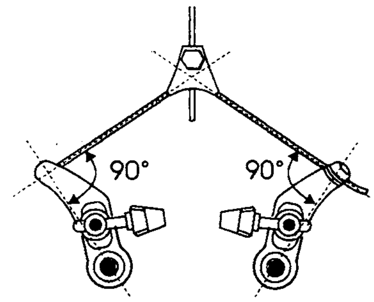


Fig. 31

The Shimano link wire system uses an integrated transverse cable that includes the main cable as half of its assembly. The main cable passes through a short piece of housing on the right side. The housing also acts as an angle gauge for establishing the perfect geometry for the brake. This assembly makes it easy to quickly and accurately set up the brakes to optimum factory specifications to achieve maximum braking performance.

The order of the setup is important. Failure to do the steps in the proper order will make it difficult to establish the correct cable geometry and will result in less than optimum performance. The basic order is as follows:

1. Set up the link wire with the correct transverse cable geometry.

2. Pre-center the link wire and calipers around the rim.

3. Adjust the shoes so they make proper contact with the rim.

HOW TO:
Setting Up Link Wire Style Cantilever Brakes

Step 1 - Check to make certain the wheels are properly centered and seated in the frame.

Step 2 - Inspect the housing for damage, proper length, and smooth routing. Correct if necessary.

Step 3 - Screw the brake lever barrel adjuster all the way in. Lubricate the main cable, if desired, and install the cable into the brake lever, making sure its head is seated properly in the holder. Route the cable through its housing through the final cable stop.

Step 4 - Remove the shoe assembly fixing nut, grease the threads and reinstall the nut. Move the shoes completely out of the way (away from the rim). Temporarily retighten in that position until later use.

Step 5 - Remove, grease, and reinstall the anchor bolt, then route the main cable diagonally through the cable carrier as shown in figure 32 position #1, passing it through the carrier housing and through the anchor bolt. Snap the main cable into position #2 so that it is completely vertical as shown. Leave the anchor bolt loose.

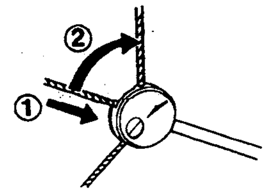


Fig. 32 -

Step 6 - Using a Fourth Hand tool, pull the cable through the anchor bolt until the end of the housing rests against it. Viewing the face of the carrier, continue pulling until the angle of the left side cable is in a straight line with the line on the carrier. Pull a little further until it matches the angle shown in figure 33.

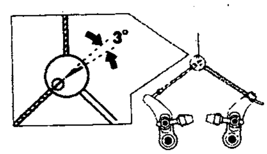


Fig. 33 -

Step 7 - Temporarily tighten the cable pinch bolt to only 5-8 in/ lbs., just enough to hold it while continuing on the following steps. Final tightening of the anchor bolt will take place in a later step.

Step 8 - Pre-center the cantilever arms by turning the spring adjusting screw on the side until the carrier is exactly centered underneath the housing stop (figure 34). Turning the adjustment screw inward will move the carrier to the right, turning outward will move the carrier to the left. Squeeze the brake lever once to guarantee the carrier stays centered. Readjust if necessary.

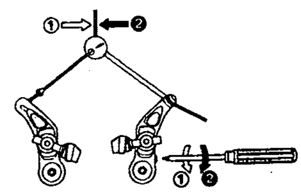


Fig. 34

Step 9 - Loosen the shoe assembly fixing nut and push the shoes inward against the rim, making sure the directional arrows are facing forward, if applicable. Slightly tighten the fixing nut to hold the shoes in position just enough so you can still manipulate them to make further adjustments. Final tightening will take place in a later step.

Step 10 - Adjust the shoes for height, interface, angle and toe-in in that order.

Height and Interface - The top of the shoe should be 1 mm below the top edge of the rim and the face of the shoe should mate with the surface of the rim squarely. This is adjusted with a combination of moving the shoe assembly vertically in the slot and angling the shoe accordingly. Figure 35 shows two possible problem areas. The example on top is too high in the slot so the shoes have to be angled downward to make contact with the rim. The example in the middle is too low in the slot so the shoes have to be angled upward. Both of these examples reduce the amount of braking power by reducing the amount of shoe contact with the rim. The example on the bottom shows the ideal position with 100% of the shoe surface making contact with the rim. Keep in mind the optimum position of the shoe assembly in the slot will vary depending on the placement of the bosses relative to the rim.

Angle - The shoe should be centered across the contour of the rim with all four corners equal distance to the rim edges. If the fixing nut was previously tightened only a small amount, you should easily be able to rotate the shoe to achieve the same appearance as Figure 36.

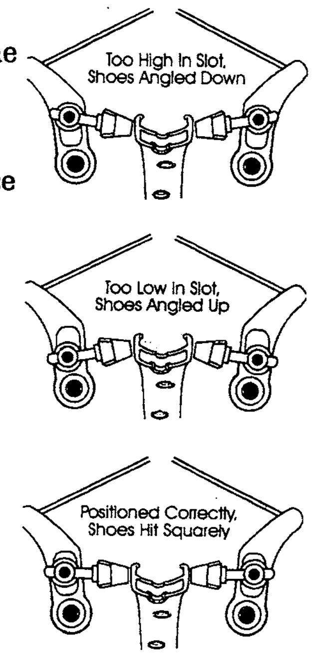


Fig. 35

Toe-in - The leading edge of the shoe should make contact with the rim first and there should be a gap at the trailing edge of .5 to 1.5 millimeters (figure 37). For those shoe designs that have built in toe-in knobs on their surface, adjust the shoe flat against the rim.

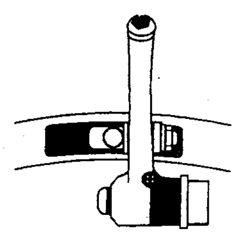


Fig. 36

Step 11 - Tighten the shoe fixing bolt or nut to manufacturer's specifications. For best results, tighten in 3 or 4 stages, checking in between each stage that the shoe did not slip out of position as you were tightening.

Caution - tightening the shoe assembly in the wrong position may distort the hardware making it difficult to readjust the shoe in the correct position!

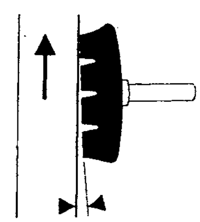


Fig. 37

Step 12 - Repeat steps 9 through 11 on the other brake shoe. It is easiest to start by setting the shoe at the same height in the slot as the first side and going from there.

Step 13 - Loosen the cable pinch bolt and allow 2 to 3 millimeters of slack to pull through the bolt. There should be a slight gap between the pinch bolt and the end of the carrier housing (figure 38). Retighten the pinch bolt to its final manufacturer's torque specifications.

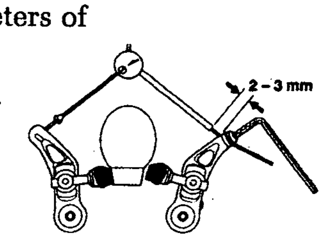


Fig. 38

Step 14- Push the carrier down from above to close the gap created in the previous step so the carrier housing is again resting against the anchor bolt (figure 39). This and the previous step are done to open up the arms to set the proper shoe to rim clearance.

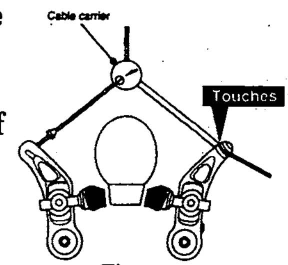


Fig. 39

Step 15 - Check the final centering of the shoes against the rim. If equal distance is not present, readjust by turning the spring adjusting screw on one or both sides of the cantilever arm.

Step 16 - Perform a failure test by firmly squeezing the brake lever up to ten times, making note of any slippage that may have occurred. Correct any problems and double check the shoe to rim clearance. Readjust the cable or shoes if necessary.

Step 17 -Install a crimp-on cable end by using the crimping area of a cable cutting tool.

Setting Up Transverse Cable Geometry for Cantilevers with Traditional Hangers

Setting up a standard cantilever brake that uses a transverse cable attached to a separate hanger can be a little tricky, because the system lacks the built-in guides of the link wire system. The following guidelines for setting up traditional systems will help you achieve optimum performance.

Wide Profile Cantilevers with Traditional Hanger

The arms of wide profile cantilevers are horizontal to the ground, which makes positioning the transverse cable at an efficient angle difficult. Since it is physically impossible to position the cable 90 degrees to the arm pivot, the hanger must be positioned as high as possible for maximum braking power. There are practical limits, of course, as to how high you can place it. The height is usually limited by an obstruction from the cable stop or stem (figure 40). Position it as high as is practical under the circumstances.

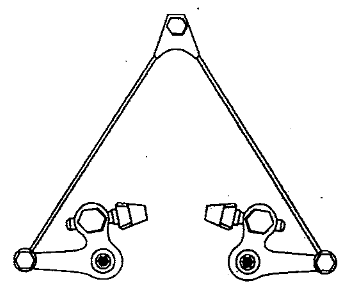


Fig. 40

Low Profile Cantilevers with a Traditional Hanger

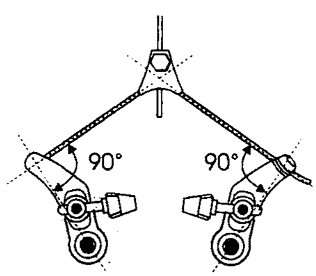


Fig. 41

The near vertical arms of the low profile design make it very easy to set up the transverse cable angle at 90 degrees to the pivot no matter what type of hanger is used. But since there are no built in gauges, it must be done by observation alone. The best approach is to follow the same procedure for the Shimano link wire system discussed earlier in this chapter.

Experiment with the height of the hanger and length of the transverse cable until everything matches as close as possible the drawing in figure 41 Then move the shoes inward and adjust them accordingly.

Special Considerations for Traditional Hanger Setups

Some combinations of components make it difficult to adjust the cable geometry to the above specifications. An example is using drop bar levers with standard cantilevers. Most drop bar levers only pull 12-16 mm of cable, which is optimal for side pull brakes. However, many standard cantilevers require up to 19 mm of cable pull, so a common problem is the lever bottoming out on the handlebar before the shoes make full contact with the rim. One way to mitigate this problem is to position the cable hanger higher than usual. A higher hanger increases the angle of the transverse cable, which moves the arms farther inward with less lever movement. Another solution is to use a lever designed for dual pivot side pulls. These may pull enough cable to work with standard cantilevers.

Customizing the Feel at the Lever

The height of the cable hanger will affect how the brakes feel at the lever. The closer you get to the 90 degree pivot angle, the higher the breaking power. However, this can create a "mushy" feel at the lever, because the high degree of mechanical advantage this position gives squashes the shoe against the rim. For a firmer feel, adjust the hanger higher. It is important to understand that this will reduce braking power, because the higher hanger changes the pivot angle away from 90 degrees.

HOW-TO:

HAYES Hydraulic Disc Brake System Bleed

Tools needed:

- T-10 Torx wrench
- 3mm, 4mm, 5mm hex wrenches
- 6mm and 10mm box/open end wrenches
- Needle nose pliers
- Hayes bleed kit (bottle, cap, hose, spring, 2 hose end fittings)
- Small catch bottle
- Isopropyl alcohol
- DOT 3, DOT 4, or DOT 5.1 brake fluid
- Spoke or rubber band
- Shop rags
- Protective glasses
- Protective gloves

Step 1 - Prepare the Hayes bleed kit.

Step 2 - Remove the wheel from the bike.Note the position of the lever on the handlebar. Remove the master cylinder, caliper, and hose from the bike.

Step 3 - Place a handlebar in the repair stand. Mount the master cylinder on the handlebar. Lightly tighten the clamp so that the lever can be rotated on the handlebar.

Step 4 - Identify the retention system used to hold the brake pads in place. Remove the pads using the appropriate method for the given retention system. Note the pad orientation- some are not symmetrical. Inspect the pads for wear or damage. Place the pads away from any possible source of contamination.

Step 5 - Inspect the caliper piston(s), hydraulic line and lever for signs of leakage. Using the closed end of an 8mm combination wrench reset the pistons so that they are flush with the caliper body. Apply pressure to the center of the piston only.

Step 6 - Rotate the lever so that the master cylinder bleed screw is the highest point in the system. Set the stroke adjuster to the middle of its adjustment range.

Step 7 - Remove the master cylinder bleed screw. Thread the appropriate fitting (plastic or metal) into the bleed port. Attach the catch bottle with red hose clamp. Close the red hose clamp. Hang the catch bottle from the handlebar with the supplied spoke.

Step 8 - Remove the caliper bleed screw from the center of the hose fitting. Thread the metal fitting for the filler bottle into the caliper bleed port. Attach the filler bottle

Step 9 - Gently pull the brake lever to the handlebar. This will remove any air trapped in the filler bottle hose and allow for fluid to be "pushed" into the system. Release the brake lever. Unclip the red hose clamp.

Step 10 - Begin applying pressure to the filler bottle, pushing fluid into the system at the caliper. Apply pressure for a slow count to 5 and then release and allow the bottle to return to its natural shape. Continue this procedure until no air and only fluid comes out of the caliper when pressure is released.

Step 11 - After all air is removed from the caliper continue squeezing the bottle until only fluid, no air bubbles, comes out of the master cylinder into the catch bottle.

Step 12 - While squeezing the filler bottle rotate the master cylinder upwards so that it is perpendicular to the ground. Quickly stroke the lever to the handlebar and release.

Step 13 - Still squeezing the bottle, rotate the master cylinder down so that it is perpendicular to the ground, then return the master cylinder to the riding position.

Step 14 - Repeat steps 12 and 13 with the handlebar pointed down at a 45 degree angle.

Step 15 - Continue squeezing the filler bottle. Once all air bubbles are removed from the master cylinder close the red hose clamp and stop squeezing the filler bottle.

Step 16 - Unthread the cap on the filler bottle 1 full turn to allow the pressure in the bottle to equalize with the room. Retighten the cap on the filler bottle. Remove the filler bottle and bleed fitting from the caliper bleed port. Allow a small bead of fluid to form in the caliper bleed port then reinstall the caliper bleed port screw. Tighten to the manufacturer's recommended torque specification.

Step 17 - Unclip the red hose clamp. Remove the catch bottle and bleed port fitting from the master cylinder. Install the master cylinder bleed port screw. Tighten to the manufacturer's recommended torque specification.

Step 18 - Clean the caliper and master cylinder with isopropyl alcohol.

Step 19 - Install the brake pads, pad spring and pad pin in the caliper. Tighten to the manufacturer's recommended torque specification.

Step 20 - Remove the brake lever from the handlebar. Install the master cylinder, hose and caliper on the bike. Locate the lever according to the rider's preference and tighten the mounting bolts to the manufacturer's recommended torque specification. Leave the caliper mounting bolts loose. Install the wheel.

Step 21 - Set the stroke adjuster to the minimum and pump the lever a few times to preset the pad spacing. Pull the lever and hold, tighten the caliper mounting bolts to the manufacturer's recommended torque specification.

Step 22 - Test the brakes by squeezing the lever several times prior to test riding. You should notice no excessive lever travel or brake fade.

Step 23 - Clean and put away the bleed kit components.

HOW TO:

SHIMANO "Shop" Hydraulic Disc Brake System Bleed

Tools needed:

Shimano Mineral Oil/Shimano Shop Bleed Kit

Plastic tire lever

6, 7 and 8 mm combination wrenches

2, 3, 4, and 5 mm hex wrenches

Small phillips screwdriver

Bladed screwdriver

Torque wrench

Needle nose pliers

Shimano bleed spacer (yellow)

Shimano travel spacer (orange)

Protective gloves

Shop rags

Isopropyl alcohol

Safety glasses

Step 1- Clamp the bicycle in the repair stand. Remove the wheel from the bicycle.

Step 2 - Remove the brake pads and spring from the caliper. To do this, you need to remove the snap ring and pad axle from the caliper. The pad axle will require either a 3 mm hex wrench or a bladed screw driver depending on the model of caliper.

Step 3 - It may be necessary to push the pistons back into the caliper to so that the bleed spacer will fit into the caliper. Clean the exposed piston with isopropyl alcohol and a cotton swab. Push the pistons into the caliper body using a plastic tire lever until they are flush with the caliper body.

Step 4 - Place the yellow bleed spacer into the caliper using the pad axle to hold it in place.

Step 5 - Rotate the brake lever so that the oil reservoir is parallel to the ground. Remove the reservoir tank cover using a small Phillips screwdriver. Be careful not to lose the small screws and or washers! Remove the diaphragm from the reservoir.

Step 6 - Install the clamp mechanism so that the compressible foam is centered over the reservoir with the flat portion of the clamp facing the handlebar. Clamp in place using the large lever with enough force to deform the foam. Hang the catch bottle from the handlebar using the provided spoke.

Step 7 - Fill the syringe with 50 ml of Shimano Mineral Oil. After the syringe is full hold upright with the plunger facing down and pull the plunger carefully to move all fluid into the syringe body. DO NOT pull the syringe all the way out. Once all oil is in the syringe body compress the plunger slowly to move any air out of the attached hose.

Step 8 - Remove the bleed nipple cover completely from the caliper. Place the closed end of the appropriate size (6, 7 or 8 mm) combination wrench onto the caliper bleed nipple. Carefully install the syringe onto the bleed nipple making sure that the hose is fully engaged. You will need to hold the syringe to keep it from coming off of the bleed nipple.

Step 9 - Open the bleed nipple by turning it counter-clockwise about 1/8 to 1/4 of a turn. Allow any air from the caliper to escape into the syringe, and then gently begin to push the syringe plunger so that fluid enters the caliper. Continue applying pressure to the syringe until you see fluid flowing through the hose at the lever and into the catch can.

Step 10 - Once the hose at the lever is full of fluid stop applying pressure to the plunger. Pull back on the syringe plunger at the caliper for 1-2 seconds to assist in removing any air trapped in the caliper. When air bubbles have settled into the syringe body, apply pressure to the plunger to force more fluid into the system. Be careful not to draw air into the system at the top.

Step 11 - Repeat this step until no air bubbles are coming out of the caliper. Close the bleed nipple and carefully remove the syringe from the bleed nipple. Wipe away any excess oil and replace the bleed nipple cover.

Step 12 - Remove the pad axle and yellow bleed spacer from the caliper body. Select the appropriate pads and pad spring, place the spring in between the pads. Compress the pad/spring/pad combo and load them into the caliper body. Reinstall the pad axle and snap ring. Place the orange travel spacer between the pads and compress and release the brake lever a few times. This entire step must be done carefully because the reservoir clamp mechanism is still installed at the lever. At the brake lever, there should be a distinct stopping point with a solid feel.

Step 13 - Carefully remove the clamp mechanism and fill the reservoir to the top and reinstall the diaphragm and reservoir tank cover. Excess fluid should overflow so it is best to have a rag around the lever to catch the excess fluid.

Step 14 - Remove the red travel spacer from the caliper. Reinstall the wheel. For post style mount calipers loosen the two 5 mm caliper fixing bolts so the caliper will slide freely on the adapter or fork. While depressing the brake lever tighten the caliper fixing bolts to the manufacturer's torque specification. For ISO mount calipers the brake pads will need to be centered over the rotor using small "panhandle" washers. This needs to be done without the brake lever being depressed.

Step 15 - Wipe down entire system with alcohol.

Step 16 - Test that the brake system has a firm lever feel and a distinct stopping point when the lever is depressed. The rotor should travel between the pads without rubbing

HOW TO:

SHIMANO "Home" Hydraulic Disc Brake System Bleed

Tools needed:
Shimano Mineral Oil/Shimano Bleed Kit
Catch bottle
Plastic tire lever
6, 7 and 8 mm combination wrenches
5 mm hex wrench
Small phillips screwdriver
Yellow pad replacement block (bleed spacer)
Protective gloves
Shop rags
Isopropyl alcohol
Safety glasses

This procedure can be used on all Shimano hydraulic disc brake systems.

Step 1- Clamp the bicycle in the repair stand. Remove the wheel from the bicycle.

Step 2 - Remove the brake pads and spring from the caliper. To do this, you need to remove the snap ring and pad axle from the caliper. The pad axle will require either a 3 mm hex wrench or a bladed screw driver depending on the model of caliper. Once the pads and spring have been removed, place the yellow bleed spacer into the caliper using the pad axle to hold it in place. It may be necessary to push the pistons back into the caliper to so that the bleed spacer will fit into the caliper. Push the pistons into the caliper body using a plastic tire lever until they are flush with the caliper body.

Step 3- Rotate the brake lever so that the oil reservoir is parallel to the ground. Remove the reservoir tank cover using a small Phillips screwdriver. Be careful not to lose the small screws and or washers! Remove the diaphragm from the reservoir.

Step 4- Remove the bleed nipple cover from the bleed nipple at the caliper. Place the closed end of the appropriate size (6, 7 or 8 mm) combination wrench onto the caliper bleed nipple. Next, place the bleed hose and plastic bag onto the bleed nipple. Make sure the bleed hose is completely seated on the bleed nipple.

Step 5- Loosen the bleed nipple by turning it counter-clockwise about 1/8 of a turn. Fill the reservoir at the lever with Shimano mineral oil. Gently depress the brake lever to begin priming the system. When the oil begins to enter the hose the fluid level in the reservoir will drop, so keep adding sufficient oil into the reservoir to keep it full, which will avoid drawing air in to the system. When oil begins to appear in the bleed hose at the caliper you can close the bleed nipple.

Step 6- Continue depressing and releasing the brake lever, making sure that the fluid is to the top of the reservoir. At this point air bubbles in the system will begin to appear in the reservoir. Once the bubbles stop appearing, depress the brake lever. The lever should have a distinct stopping point with a firm feel.

Step 7- If a firm lever feel is not achieved at this point the next course of action is to depress the brake lever and open and close the bleed nipple in rapid succession (approximately 0.5 seconds each time) to release any air bubbles which may be trapped in the caliper. Once no more bubbles appear in the bleed hose, release the lever. With the bleed nipple closed check for a firm lever feel.

Step 8- Carefully remove the bleed tube and plastic bag from the bleed nipple. Remove the wrench from the bleed nipple. Wipe away any excess oil and replace the bleed nipple cover.

Step 9 - Remove the pad axle and bleed spacer from the caliper body. Select the appropriate pads and pad spring, place the spring in between the pads. Compress the pad/spring/pad combo and load them into the caliper body. Reinstall the pad axle and snap ring. Place the red travel spacer between the pads and compress and release the brake lever a few times. This entire step must be done carefully because the reservoir is still open at the lever. Fill the reservoir to the top and reinstall the diaphragm and reservoir tank cover. Excess fluid will overflow so it is best to have a rag around the lever to catch the excess fluid.

Step 10 - Wipe down entire system with alcohol.

Step 11- Remove the red travel spacer from the caliper. Reinstall the wheel.

Step 12-For post-style mount calipers, loosen the two 5 mm caliper fixing bolts so the caliper will slide freely on the adapter or fork. While depressing the brake lever tighten the caliper fixing bolts to the recommended torque specification. For I.S. mount calipers the brake pads will need to be centered over the rotor using small "panhandle" washers. This needs to be done without the brake lever being depressed.

Step 13 – Test that the brake system has a firm lever feel and a distinct stopping point when the lever is depressed. The rotor should travel between the pads without rubbing.

Chapter 7

Headsets

Objectives:

- Identify compatible headset, frame and fork design
- Service a threaded headset
- Service a threadless headset

Headsets and Rigid Forks

The headset is the bearing system that allows the front wheel to turn, providing steering control of the bicycle. The headset's location subjects it to road shock from the constant vertical pounding of the front wheel, a condition unique to this bearing system. The other bearing systems on the bicycle rotate continuously around a circle, which means they experience a radial load. The headset bearings do experience a radial load when the fork turns, but because the steering radius is relatively small, the bearings rarely move more than a few millimeters. Therefore, the headset bearings primarily absorb the dynamic angular load from the ground. This is called a thrust load (figure 1).

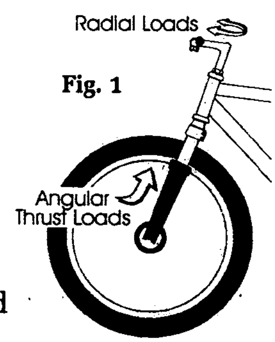


Fig. 1

Even though most headset systems historically have used ball bearings in a standard cup-and-cone design, ball bearings are actually inferior in thrust load applications. The actual amount of bearing surface area making contact with the races is small and inappropriate for the amount of impact (dynamic load) the bearings endure. Just a fraction of a millimeter of contact is being made at the top and bottom of each bearing, hardly enough for good load support. Despite this, they are still commonly used in a headsets. One reason is that they are inexpensive and easily maintained. Another reason is their ability to adjust to different load variables. The thrust load on the headset is not purely vertical: it is more angular. Ball bearings work well in this application because they are able to adjust to these loads by shifting within the

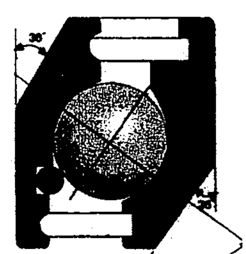


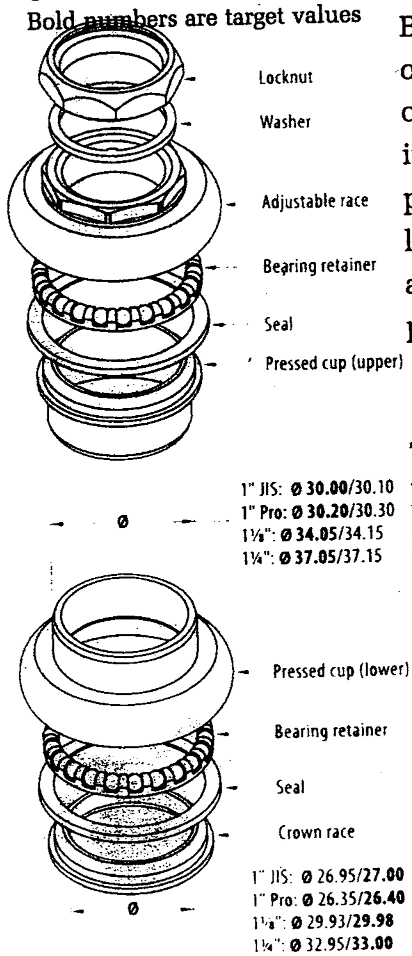
Fig. 2 - Ball bearing assembly

assembly, adapting to the subtle changes in the direction of the load. The trade-off is the bearings have a fairly short service life. The headset's lower bearings absorb most of the initial impact and are prone to contamination from the wheel, so they can wear out twice as fast as the upper bearings.

Some headsets use needle bearings. These provide more surface contact, so they can last longer than ball bearings. Needle bearings by themselves are not able to adjust to angular loads, so headsets that use them must be designed with races that "float", allowing the bearings to adapt to angular changes. Machining of the head tube and crown race becomes more important to insure proper alignment of these floating races.

Cartridge bearings are also widely used in headsets. They simplify maintenance, but under extreme conditions the cartridge bearings can deteriorate rapidly due to their inability to adjust to the dynamic thrust loads found in headsets. Better quality cartridge bearing headsets use pressed in bearings that last considerably longer because they do not shift within the cups, which avoids misalignment of the inner and outer races. In this design, the machining of the head tube and crown race is also important for a smoothly rotating system.

Fig. 3 Threaded headset assembly. Bold numbers are target values



HEADSET DESIGN

Because there are two types of fork steerers found on bicycles (threaded and threadless), there are two categories of headsets. These designs differ primarily in the method of locking the bearing adjustment in place. Threaded headsets utilize an adjustable race and locknut threaded onto the fork. Threadless systems use an adjustable race and compression ring locked in place by a top cap and the stem.

Threaded Headsets

Threaded headsets consist of two subassemblies: the lower stack and upper stack. The lower stack is located at the base of the head tube, between the frame and fork. The lower stack contains three main parts: the crown race, the lower pressed race, and the bearings. In a headset with a cup-and-cone bearing system, the crown race is always the cone and the lower pressed race is always the cup.

The upper stack contains similar parts with similar sounding names: the upper pressed race, the adjustable race, the bearings, and the locknut/spacer combination.

The upper pressed race can be a cone or a cup, depending on the design. The same goes for the adjustable race.

The crown race and both pressed races are held firmly in place by pressure (called a pressed fit or an interference fit). These parts require special tools for proper removal and installation.

STUDENT HANDS-ON:

Threaded Headset Disassembly

Tools needed:

- 5 and 6mm hex wrenches
- Cable cutters
- Vernier calipers
- Headset locknut wrench
- Headset cone wrench
- Head race remover
- Crown race remover

Step 1 - Remove the front wheel and front caliper brake. Measure and record stem height.

Step 2- Remove the handlebar and stem assembly and carefully strap to frame. The use of pipe insulation or rags is strongly recommended to protect the finish of the frame.

Step 3- Measure the gap between the locknut lip and the end of the steerer tube.

Locknut Lip Clearance = ____________

Step 4- Remove the headset locknut using the appropriate tools, and then remove any washers under it.

Step 5- Unthread the adjustable race, then remove the fork.

Step 6- Remove the upper and lower bearings.

Step 7- Remove the upper and lower head tube pressed races. Be sure the end of the tool is well seated against the inside of the race so it doesn't slip.

Step 8- Remove the crown race.

Step 9 - Clean and inspect all parts. Make note of any pitting, uneven ball track, or any other unusual wear pattern.

Headset Standard Identification

Like most bicycle components, headsets are manufactured to fit a variety of different sized frames and forks. Thread and steerer tube sizes must match, and the press fit dimensions of the three pressed races must also be compatible. The important dimensions that make up a headset standard are:

1. Steerer tube size – outside diameter
2. Thread size (if threaded)
3. Head tube pressed race outside diameter
4. Crown race inside diameter
5. Cartridge bearing dimensions
6. Stem size

Threading:
1": 1" x 24TPI
1⅛": 1⅛" x 26TPI
1¼": 1¼" x 26TPI

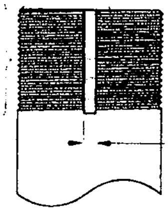


Fig. 4

Historically there have been many different threaded headset standards, often very close dimensionally. When working on headsets found on pre-1990's bicycles, consult the Sutherland's Handbook for Bicycle Mechanics 6th Ed.page 14-2 to identify the standard. Fortunately, there are fewer standards used for threaded headsets being currently manufactured. Nonetheless, accurate measurements should be taken to ensure a compatible fit. Refer to the Sutherland's Handbook for Bicycle Mechanics, 7th Ed., page 12- 6 for a list of the current headset standards.

Relationship Between Press Fits and Reamer Size

1" JIS: Ø 29.85/**29.90**
1" Pro: Ø 30.05/**30.10**
1⅛": Ø 33.90/**33.95**
1¼": Ø 36.90/**36.95**
1.5": Ø **49.57/49.61**

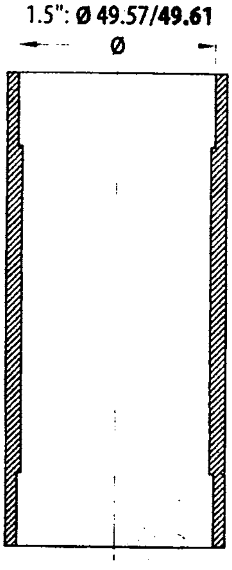


Fig. 5

Head tube pressed races and crown races are good examples of parts that are designed to be installed or removed with some type of a press. This is commonly referred to as a press fit, force fit, or interference fit. Head tube pressed races are slightly larger in diameter than the head tube, so they interfere with each other when they are forced together or apart. If the head tube pressed race diameter is bigger than the acceptable size for a good press fit, more force will be required to install or remove the race. If the interference is too little, the parts will not be held in place securely. The responsibility for maintaining the correct tolerance lies with the manufacturers.

If, upon disassembly or installation, a press fit is determined to be too heavy or too light, then careful measurements should be taken to identify the out of specification part — it may be the frame, fork or headset. For more information on headset press fit dimensions, refer to Sutherland's, 7th Ed., pages 12-6 through 12-9.

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Headset Stack Height

Headsets come in a variety of designs. Some have very low profiles, meaning the parts protrude very little beyond the head tube of the frame. Others have a very high profile.

All of the individual parts of the headset occupy space on the steerer tube of the fork - the lower stack between the fork crown and bottom of the head tube, and the upper stack between the top of the head tube and the stem. The amount of space occupied is different for every headset design, and therefore creates compatibility issues when installing a different headset on the bicycle. We can take measurements of the lower and upper stacks, add them together, and come up with a dimension called stack-height.

Knowing the stack height of a given headset allows us to easily make intelligent decisions when replacing or modifying forks, steerer tubes, or the headset itself. Measuring the stack height of the headset requires three simple measurements and a little math. See the appendix at the back of this chapter for a "how-to" on measuring stack height of a threaded system.

Once we have calculated the stack height we can use this along with a few other measurements to figure out the perfect steerer length. Most threaded forks, when purchased new, have roughly 50mm of threads already on the steerer.

Fork Alignment

Before reinstalling the fork into the frame, it is always a good idea to check the alignment of the fork. This is much easier and more accurate when the fork is off the bicycle. Forks can be misaligned for a variety of reasons: a crash, poor manufacturing tolerances, or damage during shipping, for example. Symptoms of a misaligned fork will most often show up as steering and handling problems when riding, and/or in difficulty removing and installing the wheel.

To check for dropout alignment, install the alignment tool into the dropouts, using the appropriate spacers to match the over locknut dimension (OLD). Evaluate for any gap between the cones of the tool.

The most accurate method for checking for a misaligned fork is to use a fork alignment gauge. This tool holds the fork securely in place and offers visible reference points to easily see even the slightest amount of misalignment. The gauge is capable of checking two important points - fore/aft and lateral alignment.

To check for fore/aft alignment, install the fork into the gauge. While the fork is still loose in the gauge, align the fork to the tool by sliding the gauge bar over the fork blades just below the crown. Tighten the gauge bar and lower it onto the fork blades, making sure the fork blades are touching both sides of the bar equally. Then, tighten the fork into the gauge.

Loosen the gauge bar and slide it down until it is over the dropouts. Lower it over the top of the dropouts so at least one of the dropouts is touching the bar. Examine the gap between the dropout and bar on both sides. They should be within 1 to 2 mm of each other. If not, the blades are not parallel and could be causing steering and/or handling problems and may make it difficult to install the wheel correctly in the fork.

Lateral misalignment will most often show itself by making the bicycle difficult to ride with no hands, constantly pulling to one direction, or exhibiting generally unstable steering. This type of misalignment may have been caused by a side impact of some kind. The fork blades may be bent to one side, no longer equal distance to the centerline of the steerer tube and frame. Or they may be too close or too far apart from each other, rather than being the same distance as the hub's over-locknut dimension. Lateral misalignment can be checked by placing the gauge into the dropouts and comparing how the inside of the dropouts line up with the lines on the gauge. Most rigid forks should be 100mm across from the inside face of the dropouts.

If a carbon fork is misaligned or damaged, there are some additional considerations. First, check the alignment just like any other fork with a fork alignment gauge and drop out alignment gauge. If the fork is determined to be misaligned, it should be considered unsafe. Carbon fiber may not show damage in the same way as other materials - if at all — so if there is any question about a carbon fiber fork's alignment or structural integrity, the manufacturer must be contacted for a plan of action (typically a replacement fork). *Do not attempt to fix it.*

STUDENT HANDS-ON:

Threaded Headset Installation and Adjustment

Tools needed:

- Headset cup press
- Park CRS-1 crown race setting system
- 5 and 6mm hex sockets and wrenches
- Micrometer torque wrench
- Headset locknut wrench
- Headset cone wrench

Step 1 - Install the pressed races, being careful to make sure the races are being pressed into the head tube squarely. Before removing the press, make sure the races are fully seated.

Step 2 - Install the fork crown race. Ensure that the crown race is seated squarely.

Step 3 - Grease and install the bearings, making certain retainers are installed in the proper orientation.

Step 4 - Apply grease to the fork threads and adjustable race, then install the fork into the head tube. Secure the fork by threading the adjustable race all the way down against the bearings.

Step 5 - Install any washers that were removed plus any other accessory item, such as a reflector bracket or cable hanger.

Step 6 - Grease the locknut threads and install the locknut onto the steerer tube finger tight. Inspect the gap between the locknut lip and steerer tube to be certain that it is sufficient (about 1 - 2 mm). Correct, if necessary. Do not fully tighten the locknut yet.

Step 7- Adjust the headset so the bearing play just disappears. The final adjustment should be as smooth as possible without play after the locknut is tightened.

Step 8- Reinstall the front wheel.

Step 9 - Grease the quill assembly and insert it into the steerer tube, making sure the minimum insertion line is recessed below the top of the locknut. Align the handlebars to the front hub axle and tighten the stem expander bolt to the manufacturer's torque specification.

Step 10 – Reinstall the front brake caliper and tighten to manufacturer's torque specification.

Step 11 – Check the derailleur and brake systems for proper adjustment. Readjust if necessary.

Step 12- Recheck the final adjustment of the headset and the alignment and tightness of the stem.

Step 13- Have an instructor check your bicycle. If it passes the inspection, the instructor will sign it off on your Student Daily Checklist.

Threadless Headsets

Threadless headsets are similar in design to traditional threaded systems. The primary difference is in the locking mechanism that secures the adjustment. Since the steerer tubes on the forks used with this system do not have threads, the threaded locknut has been replaced by the stem, which clamps over the steerer tube above the headset (figure 6).

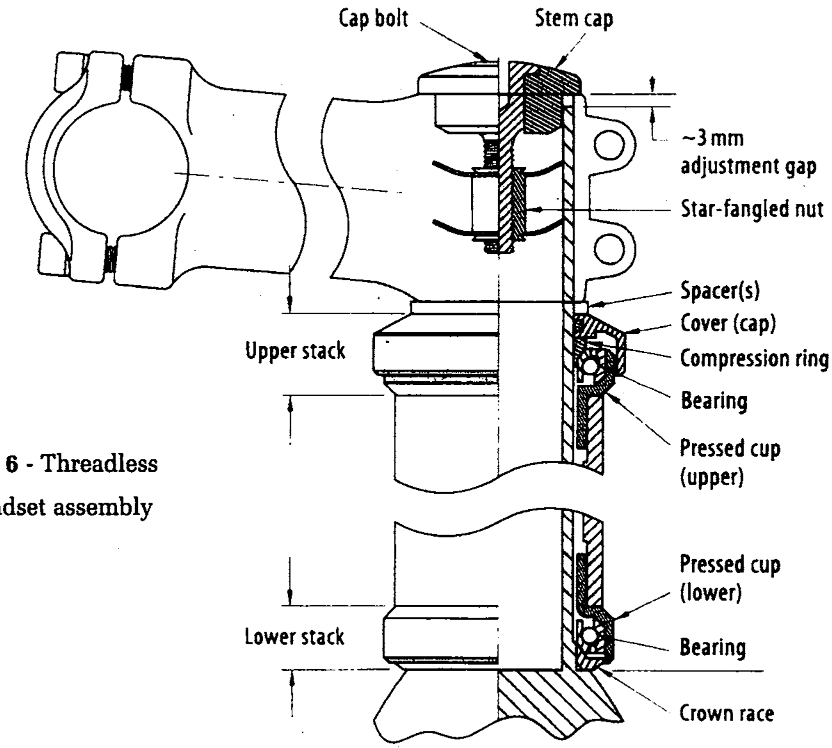

Fig. 6 - Threadless headset assembly

Threadless systems have some advantages over threaded. The stem flexes less because it clamps directly to the outside of the steerer. All things being equal, threadless stems are lighter, because they lack a quill, expander bolt and wedge. Without threads, the steerer tube can be purposely designed to be strong or light. In addition, the lack of threads means the steerer can be built with different materials, such as thin-walled aluminum alloy, or carbon fiber. From a mechanic's perspective the threadless headset is superior, requiring nothing more than a hex wrench to adjust most systems. Finally, bicycle shops like the convenience of threadless forks. These forks come in one stock length, so the steerer can be cut to fit any combination of head tube, stack height, and stem.

Threadless systems and threaded systems are incompatible. Never clamp a threadless stem around the steerer tube of a threaded fork! Because the threads are cut deeply into the walls of the steerer tube, the steerer tube is weak in that area. Clamping a stem over the threads could cause a catastrophic breakage of the steerer tube.

Around 2000, new threadless headset designs started showing up on bikes. The designs range from a slight variation on the traditional threadless system, to bike frames constructed to use a specific — sometimes proprietary — threadless system. The biggest difference between the designs is how and where the bearings are riding relative to the frame's head tube. A traditional headset uses pressed races that house the bearings above and below the head tube of the frame. For more on the traditional threadless design, refer to Sutherland's 7th Ed. pages 12-2, 12-4, 12-6, 12-7, 12-12, 12-13.

The integrated headset is a design that is unique compared to a traditional threadless headset. The major difference with an integrated headset is where and how the bearings are housed. An integrated system does not use press fit races in the frame. Instead, the bearings are placed directly into a specifically machined head tube, which means that the bearings ride inside the head tube of the frame, not on the top and bottom (see figures 7 and 8) . The result can be a system with a very low stack height that is both lighter and easier to install. This system requires the use of cartridge bearings only. Unlike other systems, the headset standard is based on the size of the bearings. Of course, the steerer tube needs to be the correct diameter for the system, but the frame will be designed for a specific type of cartridge bearing. The considerations for bearing compatibility are the outside diameter, outside contact angle and inside contact angle. The adjustment of the system is achieved using the same method as the traditional threadless headset. For more on the threadless integrated design, refer to Sutherland's pages12-3, 12-4, 12-7, 12-20, 12-21.

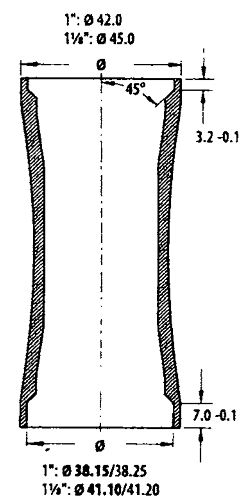

Fig. 7

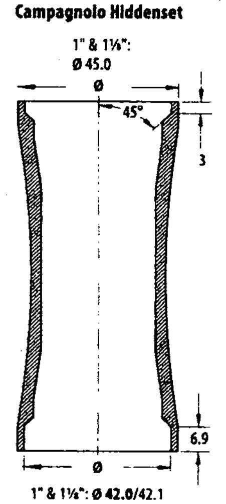

Fig. 8

The threadless semi-integrated headset is another unique system. Much like the threadless integrated, the bearings are housed inside the head tube, resulting in a very low stack height. The main difference between a semi- and fully-integrated headset is that the semi-integrated uses pressed races in the head tube of the frame. This requires a specifically machined head tube, unique to this design. The semi-integrated headset has seen very limited use on threaded systems. For more on the semi-integrated design, refer to Sutherland's pages 12-3, 12-4, 12-5, 12-7, 12-24, 12-25, 12-28, 12-29.

In recent years, the use of carbon fiber has allowed for some unique headset designs. The most notable is where there is a blending of standards. An example of this would be 1.5" bearing at the bottom of the head tube and 1-1/8" bearing at the top of the head tube. Being familiar with the many different designs and standards can help when working on newer systems.

The first few steps of the installation procedure are unique to the design. For integrated designs simply "place" the bearings into the frame. For all other systems, install the pressed races. Then install the bearings and insert the fork into the head tube. Since the fork has no threads, the adjustable race simply slides over the steerer tube and drops down onto the bearings. On top of the adjustable race is a compression ring, which is nothing more than a conical spacer, designed to center and pinch the steerer. In a cartridge bearing headset the adjustable race and compression ring may be a single assembly. On top of the compression ring, spacers are installed to customize the bicycle fit. A general rule is to use no more than 40mm of spacers, but always consult the fork manufacturer before installation. In some cases a manufacturer may specify a minimum amount of spacers in addition to a maximum.

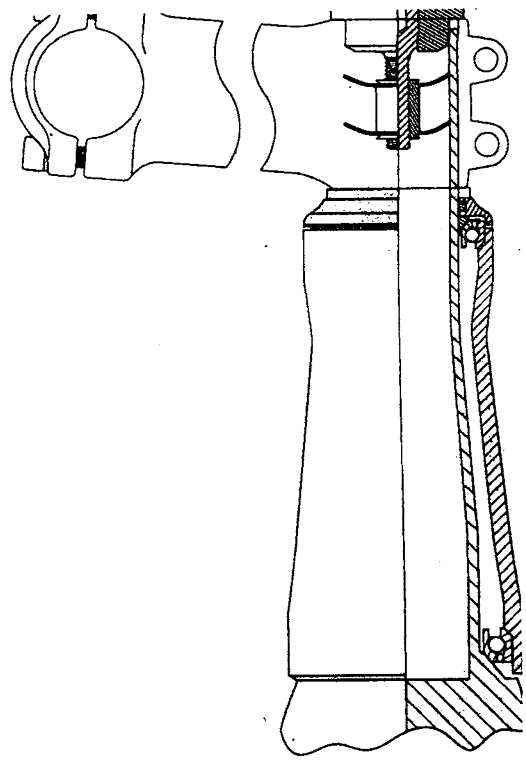

Fig. 9 -Threadless headset with blended standards: 1-1/8" at the top of the head tube and 1.5" at the bottom of the head tube

After the stem is in place, on the steerer, the top cap and bolt can be installed. The star nut is installed 15mm below the top of the steerer tube using a special setting tool. By tightening the top cap bolt, the cap compresses against the top of the stem, forcing it downward against the compression ring and adjustable race. The top cap bolt is tightened until the play in the headset just disappears. Finally, the stem binder bolts are tightened, securing the headset adjustment.

An important point about threadless systems is the difference in stack height calculation. When determining the proper steerer tube length for a given headset, the stem and spacers must also be taken into consideration. The following formula may be used for determining steerer tube length:

Head Tube Length + Stack Height + Spacer(s) + Stem Height -3 mm

= Steerer Tube Length

When the steerer tube is the correct length, you should see a gap of 2 - 3 mm between the top of the stem and end of the steerer tube (figure 10). Manufacturers may specify a gap that is different from the above recommendation, so it is important to consult the manufacturer's assembly instructions before cutting the steerer tube.

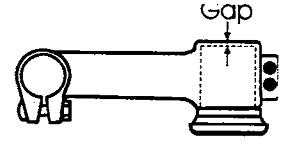

Fig. 10

Carbon Fiber Steerer Tubes

'In general, carbon fiber steerer tubes have allowed for a reduction of weight, while increasing the overall stiffness of the bicycle. As with other carbon fiber products, they have some considerations and procedures that differ from steel and aluminum steerer tubes. In some cases there may be rider weight restrictions associated with a fork that utilizes a carbon fiber steerer tube (and with other carbon products as well). Always consult the manufacturer's specifications when working on unfamiliar products.

Carbon fiber steerers do not have threads, making them compatible with threadless headset only. The use of a star nut is prohibited, because the sharp edges of the star nut will cut into the carbon fiber, weakening it. Fork manufacturers recommend a compression adjustment plug instead. The plug serves the same purpose as a star nut, providing an anchor for the headset adjusting bolt. However, the compression plug will not damage the fork, and it will add support to the steerer where the stem clamps.

Stem design must be considered as well. Never use a stem with an internal wedge or pinch bolt on a carbon fiber steerer tube. These types of stems localize the clamping force and will crack the steerer. Use only stems that have a "circumferential" clamp design. This style equalizes its force evenly around the circumference of the steerer. A stem can be identified as having "circumferential" clamp design if the slot in the steerer clamp is aligned with the centerline of the steerer tube and the stem binder bolts are perpendicular to the slot. Although most stems are now being designed to be compatible with carbon fiber steerers, if in doubt, seek manufacturer's recommendations. Never use a quill stem in a carbon fiber steerer tube.

When cutting a carbon fiber steerer to proper length, wrap masking tape around the area to be cut. This avoids splintering of the carbon fibers. Use a tungsten carbide grit type blade. If this is not available, use a very fine tooth hacksaw blade with 32 teeth per inch or more. Cutting oil is not used when cutting carbon fiber. However, water can be used to help keep carbon dust down. Be sure to take care on the last few strokes when cutting; support the end to be cut off so that you do not tear or splinter the steerer. Rotating the steerer towards the end of the cut can also prevent splintering. Check the manufacturer's recommendations on headset spacer heights as well. Some manufacturers vary from the suggested 40mm maximum to as few as 20mm. It is crucial to properly torque anything clamping on carbon fiber. Always seek manufacturer torque specifications when working with carbon fiber.

STUDENT HANDS-ON:

Threadless Headset Disassembly

Tools needed:

5 mm hex wrench

Vernier caliper

Step 1 – Remove the front wheel. Disconnect the brake caliper from the fork. Remove handlebars from the stem and carefully strap to the frame, paying close attention to the frame and the cable / housing systems.

Step 2 - Before removing the stem, measure the headset stack height. The headset stack height is the sum of the upper and lower assemblies combined. Measure each assembly record the information below.

Upper stack = 8 (8) mm   Lower stack = 12 (12) mm

Step 3 - Calculate the total stack height of the headset by adding the upper stack and lower stack together.

Total headset stack height = 20 (20) mm

Step 4 - Remove the top cap using the appropriate tool. Measure and record the gap from the top of the steerer tube to the top of the stem. If the steerer tube is already the correct length, it should be 2 - 3mm.

Gap between top of steerer to top of stem = 2 (2-4) mm

Step 5- Loosen the stem binder bolts while supporting the fork under the fork crown and remove the stem and spacers. Remove the fork from the frame. This may require tapping on the steerer tube with a rubber or plastic mallet to break the compression ring loose. With the fork out of the frame, remove the upper and lower headset bearings. Leave the pressed races in place. Clean and inspect all parts.

Step 6 - Measure the stem height and record your measurement.

Stem height = 40 mm

Step 7 – Measure the spacers and record the combined thickness.

Combined spacer thickness = 15 + 5 mm

Step 8 - Measure and record the length of the head tube of the frame.

Head tube length = 120 mm

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Step 9 - Using the values from all the measurements just taken, calculate the optimum length for the steerer tube using the following formula:

	210	Total headset stack height
+	40	Stem height
+	20	Combined spacer thickness
+	120	Head tube length
-	2	Gap between top of steerer to top of stem
=	198	Steerer tube length

Subtract

5mm spacers minimum usually

Step 10 - Double check the measurement just calculated by measuring the actual steerer tube from the base of the crown race seat to the top of the steerer tube. If all the previous measurements were accurate, this value should match the steerer tube length calculated in Step 9.

Steerer tube length = 198 mm

STUDENT HANDS-ON:
Threadless Headset Reassembly

Step 1 - If reinstalling the existing headset, clean and inspect all of the races prior to installation.

Step 2 - Apply grease to the upper and lower bearing cups. Install the bearings.

Step 3 – Install the fork and adjustable race.

Step 4 - Apply a small amount of grease to the inside of the compression ring. Install the compression ring and cover assembly. Wipe the steerer tube of excess grease.

Step 5 - Install the headset spacers and stem. Check for 2 - 3 mm gap from steerer to stem.

Step 6 - Install the top cap and bolt assembly, thread down finger tight.

Step 7 – Reinstall bars in stem with proper cable routing. Make sure the brake levers are oriented 45 degrees from the ground. Tighten the handlebar clamp bolts to manufacturer's torque specification.

Step 8 – Adjust the headset as smooth as possible with no play. If the adjustment feels correct, install front wheel, align stem and tighten stem binder bolts to the manufacturer's torque specifications.

Step 9 – Reconnect the front and rear brake cables. Confirm proper adjustment of the brake systems, adjust if necessary. Perform a brake safety check by actuating the brakes firmly several times to ensure proper operation.

Step 10 – Reconnect the derailleur systems if necessary. Confirm proper adjustment of the derailleur systems, adjust if necessary.

Step 11 – Have an instructor check your bicycle for final inspection. If it passes inspection, the instructor will sign off on your Student Daily Checklist.

ADDITIONAL READING ABOUT STEMS, HANDLEBARS, HEADSETS, AND RIGID FORKS

The purpose of this list is to provide some alternate sources to help you learn the material covered in class. There is no requirement to do any of this reading. Read as little, or as much as you would like.

Sutherland's Handbook for Bicycle Mechanics (6th Ed):

Handlebars and Stems, Page 14-20

Headsets, Pages 14-1 through 14-19

Sutherland's Handbook for Bicycle Mechanics (7th Ed):

Stems and Handlebars, Pages 13-2 through 13-7

Headsets, Pages 12-1 through 12-29

Web Resources:

Cyclingnews.com:

Headset Standards and Nomenclature:

www.cyclingnews.com/tech/fix/?id=howfix_headtypes

King Cycle Group

www.chrisking.com

Cane Creek

www.canecreek.com/tech-center/headset/shis

FSA

http://www.fullspeedahead.com/

CHAPTER APPENDIX

STUDENT HOW-TO

Measuring Threaded Headset Stack Height

Tools needed
Vernier caliper
Ruler

Step 1 - Measure the lower stack by assembling the three main pieces and holding them together (the crown race, bearing retainer, and lower pressed race). Be certain the retainer is in its proper orientation. Carefully measure the lower stack by placing it between the calipers as shown in figure 11. It is a measurement from the bottom of the crown race to the head tube seat of the lower pressed race (not to the part that extends into the head tube). Another way to look at it is you are measuring only the parts that would be fully visible if the lower stack were installed into the head tube. Measure in millimeters to the nearest 0.1mm.

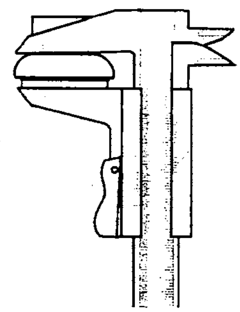

Fig. 11

Lower Stack = ____________

Step 2 - Measure the upper stack by assembling and holding together the upper headrace, bearing retainer, adjustable race, spacer(s) and locknut (figure 12). If you earlier removed a reflector bracket, cable hanger, or other accessory item from underneath the locknut, include it as well. Measure from the top of the locknut to the head tube seat of the upper pressed race. Again, you are measuring only the parts that would be fully visible if the upper stack were installed into the head tube. Measure in millimeters to the nearest 0.1 mm.

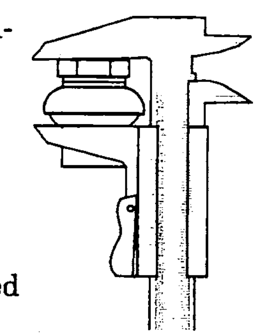

Fig. 12

Upper Stack = ____________

Step 3 - Measure the locknut lip thickness by inserting the depth gauge from the top of the locknut to the inside edge of the lip. Some locknuts have seals below the lip, so measure to the inside edge of the seal. Measure to whatever would seat against the end of the steerer tube if the locknut were threaded onto it.

Locknut Lip Thickness = __________

Step 4 - Determine dimension "A" for your steerer tube by inserting the fork into the head tube and measuring the amount of protrusion above the top of the head tube (figure 13). Be sure to hold the fork tightly against the bottom of the head tube with the crown race seat against the head tube face.

Fork Dimension A = __________

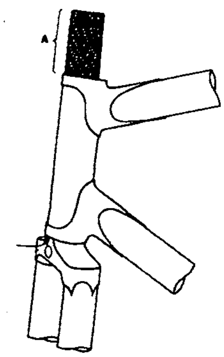

Fig. 13

Step 5 - Calculate the stack height of the headset by re-entering your stack height measurements below and using the following formula:

Lower Stack____ + Upper Stack____ - Locknut Lip____ = _____

Step 6 - Calculate what the clearance between the locknut lip and the end of the steerer tube would be if the headset and fork were fully installed by using the following formula:

Headset Stack Height____ - Fork Dimension A____ = ______

Step 7 - Measure the head tube height of the frame, from face to face, and determine what the perfect length steerer tube should be based on the current stack height. Use the following formula

Head Tube Height_____ + Stack Height_____ - 2mm = _____

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Chapter 8

Suspension Forks, Frame Materials, Frame Preparation, and Frame Construction

Objectives:

- Understand basic principles of suspension
- Identify components of suspension forks and shocks
- Gain ability to tune suspension to a given rider
- Understand and identify different construction methods, and how they are affected by heat during construction
- Understand proper procedures for frame prep and alignment

Suspension has been widely and rapidly adopted by the bicycle industry, and the technology becomes more sophisticated every year. It's now rare that a mountain, hybrid, or comfort bike does not come equipped with some type of suspension.

Bicycle suspension technology is hardly a new development. When the first RockShox fork was introduced in 1989, it was marketed as "motorcycle technology for bicycles" and was seen as revolutionary by many in the bicycle industry. However, while materials and manufacturing processes have greatly improved, many of the suspension products in use today are reworked or updated variations of designs developed in the late 1800's. The main reason bicycle suspension seems new is that, around the beginning of the 20th Century, most bicycles abandoned suspension due to the introduction of pneumatic tires.

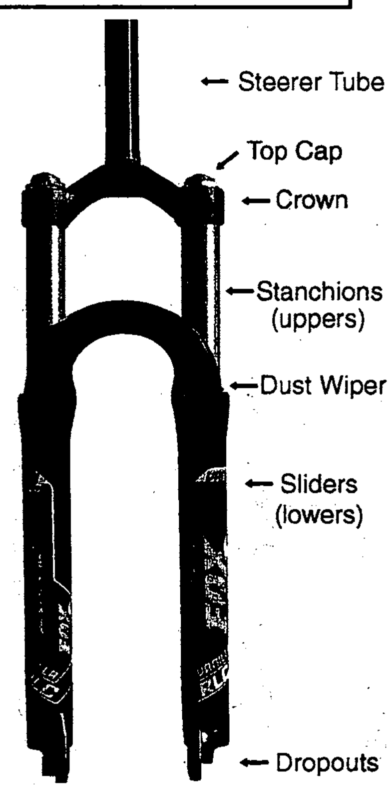


Fig 1 - Suspension components

Support Parts 3-5 years By Manufacturer

Most contemporary suspension forks are of a telescoping design, but there have been linkage designs as well (see figure 2). Most telescoping designs utilize a bushing system installed into the lowers (sometimes called sliders), which slides up and down the stanchion tubes of the upper assembly that is attached to the fork crown (see figure 3).

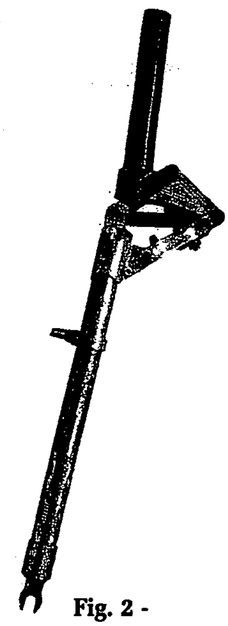


Fig. 2 -
Linkage fork

In general, suspension serves two main functions: to enhance comfort and control. By absorbing shock that would normally be transmitted to the rider, a suspension system allows the rider to travel farther, with less fatigue, over rough terrain. A suspension system also allows the rider to maintain better control of the bicycle, because it serves to keep the tires in contact with the ground.

The priority, or balance, of comfort and control will change with the intended use of the system. For example, inexpensive suspension forks (like those seen on comfort bikes and/or kids' bikes) are intended primarily to isolate the rider from the terrain, making the ride more comfortable. In these suspension systems, lower cost parts and materials are used, as well as simpler designs. These low-end forks achieve a measure of rider comfort, but their performance doesn't match more sophisticated designs. In suspension systems where performance is the main concern, more exotic materials will be utilized along with more elaborate internal spring/damper systems to precisely control suspension movement. These systems will consequently be more expensive.

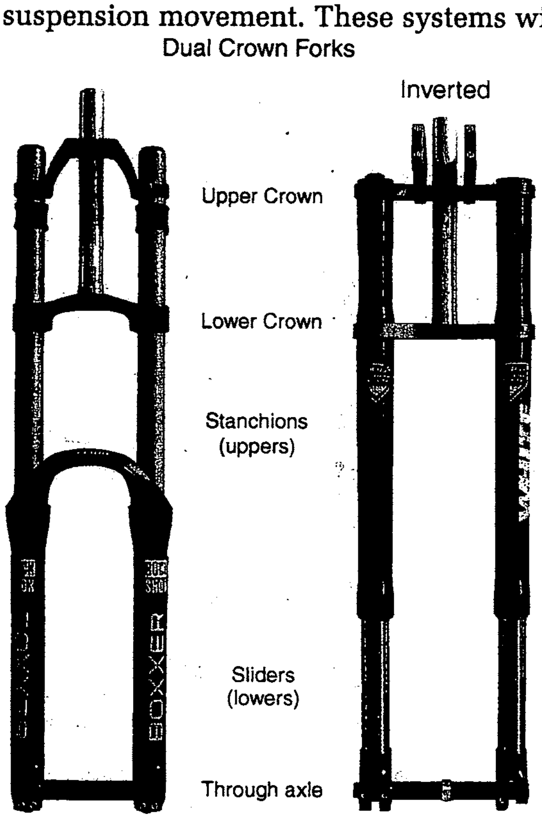


Fig. 3

Springs

Suspension systems are made up of three components: the chassis, a spring and a damper. The spring allows movement to take place, and the damper keeps that movement under control. The spring not only supports the weight of bike and rider, maintaining the bike's ride height, it also enables the suspension to absorb ground impact. The spring stores the energy of the impact, and then releases it, returning the wheel to its original position. Springs can be made from elastomers (usually some formulation of urethane), coiled metal (usually steel or titanium), or a chamber of air.

Elastomers

Elastomer springs are generally made either of solid urethane or microcellular urethane (referred to as MCU), the latter being infused with small pockets of air. Different spring rates are achieved by choosing an elastomer of a different hardness, or by combining different elastomers. The hardness of elastomers is expressed in a measurement called durometer. A higher durometer means a harder elastomer, which is more difficult to compress. However, most manufacturers use a color coding system in lieu of actual durometer numbers. Current elastomer sprung forks are typically seen only on lower-priced bikes. Elastomers themselves are inexpensive, and, because they rebound slower than they can be compressed, they can also be used without a damper, further reducing manufacturing cost.

Coil Springs

Coil springs are typically wound or coiled wire made from steel or titanium (figure 4). They are categorized by their spring rate, which is the spring's resistance to compression. This is typically listed in pounds per inch (lbs./in.). For example, a 500 lb. spring would require a weight of 500 lbs. to compress it one inch. The gauge, diameter and/or spacing of the coils can be manipulated to achieve the appropriate spring rate for a given suspension design. Coil sprung suspension can give a very supple ride in comparison to elastomer or air sprung suspension. However, in contrast to the way an elastomer spring works, a coil spring will return nearly all the energy stored on compression. This means that a damper is almost mandatory with a coil sprung suspension system, particularly on the rebound stroke. A coil spring usually has, by design, a linear spring rate. For example, a coil spring with a linear rate might require 100 lbs. to compress it one inch, 200 lbs. to compress it two inches , 300 lbs. to compress it three inches, and so on.

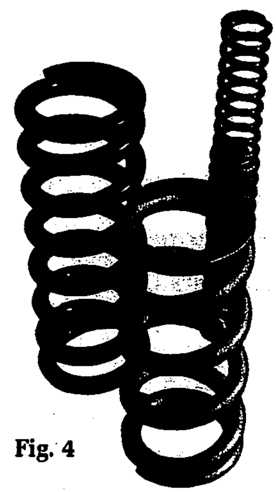


Fig. 4

Air Springs

Air springs are utilized when light weight and a finely tunable system are required. Air springs have a number of benefits. First, the air spring is lighter than a coiled metal or an elastomer spring. Second, by adding or releasing small amounts of air, the air spring can be tuned more precisely than elastomer or coil springs. By changing the air pressure, the spring can be made stiffer or softer to suit different rider weights. Also, by its very nature, an air spring has a progressive spring rate. That is, as the spring compresses, progressively greater force is needed to continue to compress it. Unlike the example of a linear rate mentioned above, a spring with a progressive rate might require 100 lbs. to compress it one inch, 250 lbs to compress it two inches, and 400 lbs. to compress it three inches.

Dampers

Without the use of some sort of damping system, the action of the spring can be so unpredictable that it compromises bike handling. The addition of a damping system regulates the movement of the spring.

Suspension moves in two directions, called the compression stroke and the rebound stroke (see figure 5 on page 8-6). The compression stroke is the direction a suspension component moves when absorbing an impact, or from rider induced movements. The rebound stroke is the direction the component moves as it returns to its neutral state after absorbing the impact.

A compression damper regulates the speed of movement of the suspension system on the compression stroke. A rebound damper provides the same regulation on the rebound stroke. Typical damping media include oil, air, or simple seal friction.

Friction

This type of damper is found only on very inexpensive forks, and in fact it's not really a separate damper at all. It relies solely on the friction created by tight bushings and/or seals, which is used to create the "feel" of damping. As the bushings or seals wear, the damping effect diminishes.

Air Dampers

Air dampers can be used as an additional means of reducing weight. However, air is compressible and is much more affected by temperature changes than oil, so air dampers can function inconsistently. Therefore, their use is limited.

Oil Damper

Oil is the most widely used damping medium for bicycle suspension. This is due to oil's low compressibility and consistency in performance. There are a couple of common methods to adjust the performance of an oil damper. The most common method of adjustment is an external control that regulates the speed of oil transfer from one location to another inside the damper. Another type of adjustment may be to change the volume or weight of the oil.

Suspension Service

Although some suspension systems can be quite complicated, any shop should be able to offer at least basic suspension service. While there are some suspension components that the manufacturers prefer to work on themselves - many rear shocks, for example - many of the most common suspension service procedures can easily be performed by a shop. To assist mechanics in servicing suspension systems, many manufacturers maintain extensive technical archives on their web sites and have full-time technical departments reachable by phone. Also, the service manuals for suspension forks tend to be much more comprehensive than those for other bicycle parts.

Before committing to any suspension work, find out if there are special tools necessary. Some forks require specific bushing removal or installation tools, valve body clamps or cartridge service tools. You may conclude that the tools needed are too expensive to make the job profitable. On the other hand, if you anticipate working on more forks of the same model, the investment will pay off. You may also find that the tools of one manufacturer will work with other manufacturers' forks. Nonetheless, if the shop has to acquire the tools for a particular procedure, or decides to return the component to the manufacturer for service, make sure the customer is informed of the additional time the service will require.

Suspension service can be divided into two main categories: basic service and advanced service. Basic service should be within the capabilities of any shop, and most home mechanics. This entails any service that requires nothing more extensive than removing the top caps. Advanced service will require the fork or shock be taken apart (separating the two halves) to access the internals. Before attempting advanced service the mechanic or shop may need to invest in specialty tools and/or training.

Basic Suspension Service

Basic suspension service should start with a thorough cleaning of the fork or shock, and an inspection for any oil leaks. Once the component is clean the mechanic should check for any external damage. On a fork; this might include damage to the stanchions, sliders, dropouts, fork crown, steerer tube, air valves, etc.

After evaluating the fork or shock, other basic service procedures may follow. For forks these may include replacing used oil, changing the oil weight, or changing the oil volume in the damper cartridge. Replacing air valves, changing travel spacers, or swapping out springs can also be done. Most of these tasks can be accomplished from just underneath the topcaps. On a rear shock, basic service includes cleaning / inspecting and changing a coil spring or air spring pressure.

Advanced Suspension Service

Advanced service procedures will extend to replacement of worn bushings, overhaul or replacement of the damper assembly, overhaul or replacement of an air spring assembly, or replacement of the entire upper or lower fork assembly. Most of these procedures will require separation of the uppers from the lowers (in the case of a fork). In addition they may require the use of special tools (flat ground sockets, snap ring pliers, bushing tools, etc) and specialty parts (crush washers, bushings, glide rings, o-rings, etc). Some of these tools and many of the parts are manufacturer-specific.

STUDENT HANDS-ON:

Suspension Fork Disassembly and Reassembly

The hands-on instructions will be supplied on handouts in class to allow us to keep up-to-date with suspension technology.

Suspension Tuning

Regardless of the level of suspension repair service a shop decides to offer, every shop should be able to offer suspension tuning. The goal of suspension tuning is, simply, to give the customer a balanced bike. This in turn offers a more enjoyable ride and better control of the bicycle. It is important to follow the correct sequence when tuning suspension.

Before tuning the system, you will need to know some basic information. The rider's weight will determine the proper spring rate. Knowing the type of riding and terrain will be necessary for setting damping and travel. Knowing the type of bike the suspension will be used on will also affect how you adjust the suspension for optimum performance.

To get the best performance from a suspension system, it is best to approach tuning methodically. There is a widely accepted sequence to tuning. In addition to following the steps detailed below, you should keep detailed notes about each change made in the suspension system, and the rider's feedback on each of those changes. Over time, the data you accumulate will help you more quickly tune suspension for other riders, and for particular riding conditions found in the geographic area served by your shop.

The Tuning Sequence

1. Sag – The term sag refers to how much the suspension system's spring compresses due to the static weight of the rider. Setting up the proper amount of sag is the first step with any suspension tuning. You must ensure the proper spring rate is being utilized for the rider's weight and the bike's intended use. No other adjustments can be properly set up until the right spring rate has been determined. If you do nothing else for a customer before you send them out the door with a new bike, take the time to set up the proper amount of sag. This allows the suspension to respond to both holes and bumps.

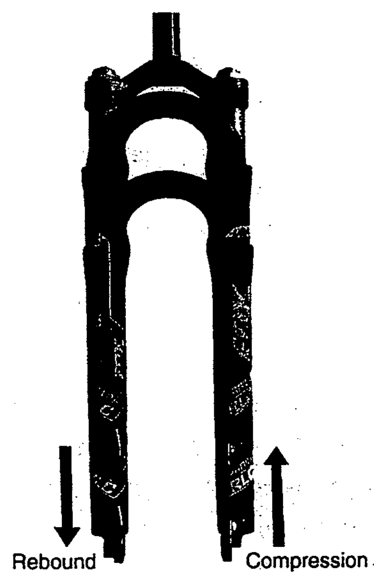


Fig.5

2. Rebound Damping – This determines how fast a suspension system returns to its neutral position after absorbing the energy of an impact. Rebound settings have a close correlation to spring rate. Rebound settings can be fine-tuned to the rider's preference to compensate for his or her riding style and the terrain.

3. Compression Damping – This determines how fast the system absorbs the energy of an impact or rider-induced movement. On some forks there may not be any external adjusters for compression damping. In this case, your options are generally limited to changing the oil weight and or oil volume. If the fork has been manufactured with external compression damping adjusters, look for the following:

> **Lock out** – This type of adjuster is usually seen on cross-country type forks and shocks. This will reduce low shaft speed movement induced by the rider, and "locks out" the suspension, which is especially useful on extended climbs.
>
> **Travel adjust** – This adjuster is seen in a variety of forks, but is usually found on longer travel forks. This control shortens travel, which steepens the geometry of the bike to provide more control on steep climbs.
>
> **High Speed** – High speed compression damping adjusters are found typically only on the most expensive forks. High speed adjustment allows for fine-tuning the system's reaction to large drop-offs or square-edged bumps.
>
> **Low Speed** – This adjustment is used to give the fork/shock a more stable feel or to further isolate the bike from rider induced movement. This is also usually found on higher priced forks and shocks.

FRAME MATERIALS

The material used to construct a bicycle frame greatly affects the bike's ride characteristics, weight, and appearance. For better or worse, many consumers buy bicycles solely based on their frames' material, or that material's reputation. For this reason, it is of extreme importance to realize the benefits and limitations of each.

There are three terms that are often used to compare the properties of different frame materials. The first is modulus of elasticity. This is the measure of how easily a material returns to its original shape when subjected to bending or stretching. A second important term is yield strength. This is the amount of force necessary to bend a material to the point that it does not return to its original shape. Finally, materials also have tensile strength, which is the amount of force required to physically tear or break the material.

Steel

Historically, steel has been by far the most common frame material on the market. It is an exceptionally versatile material, and can be made to exhibit a wide range of physical and mechanical properties. When formed into bicycle tubing, it is light, strong, and comparatively inexpensive. Also, since steel is so heavily used in other industries, tubing is available in a wide variety of dimensions.

The basic ingredient in steel is the element iron. Like many elements, iron in its pure form is not suitable for lightweight, high performance structures. When carbon is added to iron, in amounts up to 2%, its properties can become much more desirable. The majority of bicycles in production are fabricated from approximately 0.3% carbon steel. One type of carbon steel used frequently in low-end bikes is commonly referred to as high-tensile steel. This is a reference to this particular steel's strength as compared to other, inferior carbon steels. With the addition of certain other materials, however, even greater strength and durability can be achieved.

Common Alloys Used in Steel Tubing

1. Chromium
2. Molybdenum
3. Vanadium
4. Manganese
5. Niobium
6. Nickel
7. Cobalt

The process of adding one metal to another is called alloying. Because the percentages of alloying elements are low in the steels used in the bicycle industry (relative to iron content), they are referred to as low-alloy steels. The most common low-alloy frame builders use is chromoly. This term comes from the two principle alloying elements, chromium and molybdenum. On many low to mid-range bikes a mix of carbon steel and chromoly tubes affects a compromise between cost and weight.

Other elements are sometimes added to enhance specific properties of the steel. For example, Columbus offers a line of Nivacrom tubing, so named because of the addition of niobium and vanadium. Reynolds uses an alloy comprised of manganese, molybdenum and several other elements in lesser amounts. At least one major tubing manufacturer makes a stainless steel tube set available. Stainless steels are characterized by their high chromium content, which greatly improves oxidation resistance.

Most metals' characteristics can also be controlled by heating and cooling, a process called heat treatment. This term encompasses a large variety of processes, with many different goals. Almost all steels respond to some form of heat treatment; its hardness and tensile strength can be significantly increased by such processes.

Aluminum Tubing

Light weight and low cost have made aluminum a popular frame material. Pure aluminum is unsuitable for bicycle tubing, but many alloys exist that bring aluminum's mechanical characteristics up to the standards required for the rigors of bicycling. The most common alloys used for bicycle frames are those in the 6000 and 7000 series. The element scandium can be alloyed with aluminum. Frames of this alloy are marketed in the bike industry as Scandium; however only between 0.1% and 0.5% scandium is present in the alloy. This element improves the grain structure of aluminum in the welded areas of the frame, and allows builders to use somewhat smaller diameter tubing. Alloy designations and their primary alloying element are explained in the chart below.

WROUGHT ALUMINUM ALLOY DESIGNATIONS

Aluminum, 99.00% pure and greater	1xxx
Aluminum alloys grouped by major alloying element(s):	
Copper	2xxx
Manganese	3xxx
Silicon	4xxx
Magnesium	5xxx
Magnesium and Silicon	6xxx
Zinc	7xxx
Other elements	8xxx

Aluminum bikes can either be welded or bonded. This decision often depends on the particular alloy used. For instance, 6000 series alloys are usually welded, whereas most 7000 series alloys are better off being bonded, due to loss of the material's integrity in the weld zone.

One potential drawback of aluminum frames is a tendency to deliver a harsh, stiff ride. Riders of aluminum bikes sometimes complain of their lack of shock absorption, resulting in the cyclist's premature fatigue. On the other hand, some riders praise aluminum's stiffness, interpreting its feel as responsive and efficient. Aluminum is not an inherently stiff material, however. In fact, pure aluminum's modulus of elasticity, a mechanical measure of stiffness, is only one third that of steel. Rather, the dimensions of tubing are manipulated by the frame builder to achieve certain properties.

Why, then, does it feel so stiff? And why would a manufacturer purposely build such characteristics into a frame? This apparent paradox is explained by the fact that aluminum's fatigue strength, its ability to withstand many cycles of stress, is somewhat less than that of other materials. This is not to say that aluminum is necessarily inferior. All materials, used for bicycles or anything else, have a fairly narrow range of dimensions that affect the mechanical properties desired for any particular application. In order to build reliable aluminum bikes, many designers have chosen to limit the flexure of the frame by increasing the stiffness of the frame tubes. This can be accomplished two ways: either by increasing wall thickness of the tubes or by increasing their diameter. The weight penalty that would have to be suffered by only using thicker tube walls is too great, so the tube diameter is increased as well, sometimes dramatically. This accounts for the "fat tube" look that is typical of aluminum frames.

Titanium

Titanium tubing is available in all major dimensions and a few different alloys that are suitable for bicycles. Titanium's excellent strength-to-weight ratio, fatigue and corrosion resistance, and resiliency make it the preferred material for more than a few bicyclists. Titanium bikes are not cheap, however. This is not because of titanium's rarity as an element. In fact, it is the fourth most abundant metal; huge amounts of titanium dioxide are present in beach sand. The high cost of titanium bikes is due to the extensive energy involved in processing, and highly skilled labor required by the frame builder.

Commercially Pure Titanium

Titanium that is not alloyed with another metal is called commercially pure or CP. The first production titanium bicycle, the Teledyne Titan, was constructed of CP titanium. Teledyne Linair introduced the Titan in 1973. Although these bikes had a less than stellar reputation, the Titan paved the way for the high-performance titanium machines we see today.

Although designated "pure," CP titanium usually has some amount of oxygen mixed with it. The oxygen atoms are small enough to fit in the spaces, or interstices, between the titanium atoms. The strength of CP is affected by the interstitial oxygen content. CP titanium alloys are referred to by their American Society for Testing and Materials (ASTM) grade designation number ASTM grades 1 through 4 are all CP grades, grade 4 containing the most oxygen.

Although strength increases with interstitial oxygen content, CP grades of titanium have low to intermediate strength as compared to other alloys. CP is less expensive, though, and can be used for bicycles if cost is more of a concern. Some manufacturers only use CP in less critical areas of the frame — seat stays and top tubes, for example. Other small frame fittings, such as cable stops and shift bosses, can also be made from CP titanium.

Other Alloys Used in Titanium

As with steel and aluminum, there are countless alloys of titanium available, but only a few are presently used for bicycle construction. Those in use, however, were originally developed for the aerospace industry. CP tubing has been used for many years in aircraft hydraulic systems, but a new alloy was sought that would decrease the weight of the system. A 3% aluminum, 2.5% vanadium alloy was chosen for this application because it proved sufficiently malleable to form tubing, and offered good strength characteristics. As it turns out, this 3/2.5 alloy is the one most used on high quality titanium bikes today. The 6/4 alloy has seen limited use in bicycles, mostly in dropouts and other frame fittings where high strength is crucial. 6/4 tubing is available, but at nearly twice the cost of 3/2.5. Nonetheless, it does see some use in the bike industry.

Carbon Fiber

Thomas Edison gets the credit for the first purposeful creation of carbon fibers. In 1878, he converted cotton fiber (and later, bamboo) into carbon in his search for lamp filament material. It wasn't until the 1960's that carbon fiber was produced in large amounts, and even then it was still too expensive for bicycles. Over the past couple of decades though, its price has dropped dramatically, and carbon fiber is now used extensively in bicycles and many other sports applications.

Unlike the other materials discussed in this section, carbon fiber is classified as a composite. As opposed to an alloy, which is comprised of one or more metals dissolved within another metal, a composite is a combination of two or more materials that have an interface, but retain their individual characteristics. Composites typically contain a reinforcement (in the form of fibers or particles) supported by a binder (the matrix).

There are three major sources for carbon fiber, also called precursors. These are rayon (a wood fiber product), polyacrylonitrile (PAN), and petroleum pitch. The PAN precursors are used most often, being very cost-effective and demonstrating a high tensile strength. In closely controlled situations, the carbonizing of these materials results in a low-density, high-modulus continuous fiber. These fibers can then be used much like glass fibers are used, as reinforcement in a resin system to fabricate structural components.

Once the raw carbon fiber is produced, it is spun onto a spool and later woven into a fabric. At this stage it can be wrapped around a mold or tube, or placed in a mold, alternating the carbon fiber fabric with layers of resin. The resin acts as the matrix, that is, the material used to bind together the reinforcing fibers.

Butting

Another important distinction between tubes is whether or not they are butted, and if so, what the butting configuration is. Butting is a process whereby the tube walls are made thicker on the ends of the tube than the remainder of the tube. Tubes can be single butted (thicker at one end), double butted (thicker at both ends), or triple butted (thicker at both ends, but with three different thicknesses through the length of the tube). Tubes that are not butted, but rather have a constant wall thickness are called straight gauge. Steel, aluminum, and titanium tubes can all be butted, but the process by which this happens differs somewhat among the three.

Several benefits accrue from butting. The most obvious is weight savings. Butting also serves to strengthen the end of the tube at the joint, where the most stress occurs. The thicker tube end also helps to alleviate some of the inevitable weakening of the metal that occurs as a result of welding or brazing. Additionally, the butted sections of the tube tend to be less flexible than the middle, so stress at the joints is directed to the center of the tube. Finally, butted ends provide a "safety zone" for the frame builder, making the joining process somewhat more forgiving of excess heat.

FRAME CONSTRUCTION

The terms soldering, brazing, and welding are often used interchangeably. It is important to realize, however, that there are distinct differences between the three. Soldering is a joining process that produces coalescence of materials by heating them to suitable temperature, then adding a dissimilar material, or filler whose melting point is below 800° F. Soft solders are usually lead-tin alloys.

Brazing is quite similar, although in this process the filler material's melting point is above 840° F., but still below that of the parent material. Many different filler alloys are available, but frame builders usually use silver-copper alloys and copper-zinc (brass) alloys.

Welding is a significantly different process, in which parent materials are heated to their melting point in order to produce a localized union. Filler material may or may not be used, but all welds on a bike frame should contain some filler. In most cases it is desirable to use a filler metal with an identical alloy composition of that of the parent, although this is not always the situation while welding bicycle frames.

Brazing

Oxy-acetylene brazing is a popular method of frame construction, although not as much as in years past. This is largely due to its expense relative to TIG welding in a high-production setup. Brazing is a more time-consuming process, both in the actual joining of the tubes and in the follow-up work to improve the aesthetics of the completed joint. Also, the filler material can be costly, especially if silver alloy is extensively used.

There are, however, several important advantages to brazing. One big consideration, especially to the small-scale frame builder, is that brazing equipment is significantly less expensive than that required for TIG welding. Another advantage is that brazing allows the builder a different type of artistic expression than welding does. Lugs can be shaped and filed, and fillets can be sculpted to create a personalized look. Finally, brazed frames are generally easier to repair than those that are welded. Experienced frame builders are sometimes able to replace braze-ons, dropouts, and even entire tubes on a damaged frame.

Brazing Equipment

The hardware used for oxy-acetylene brazing is fairly straightforward. It consists of a fuel gas cylinder (acetylene), a combustion gas cylinder (oxygen), a regulator and gas line for each, and a torch (figure 6). Optional to this basic setup is a third gas flux cylinder, which bathes the joint in liquid flux, explained below.

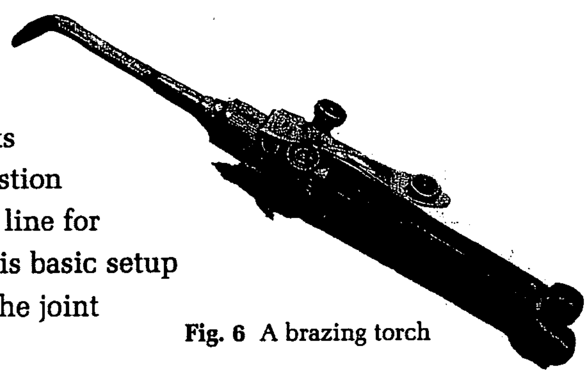


Fig. 6 A brazing torch

Brazing Materials

Along with oxygen and acetylene, there are other consumables required for brazing, these being filler material and flux. As mentioned above, silver or brass may be used as filler, depending on the particular joint and the favored technique. Silver alloys melt at a lower temperature (BAg-7, 56% silver melts at 1205° F) and flow faster than brass. This makes it ideal for joints with a tight fit, such as a lugged intersection, or for delicate operations where excessive heat could be damaging, such as applying cable stops or shift bosses.

Brass works especially well in situations where more filler material is needed, as its melting characteristics allow the brazer to "pile up" the material for greater structural integrity or cosmetic appeal. For this reason, it is used while fillet brazing, and to affix dropouts. Brass does require more heat to become molten (approximately 1500°F), but as it is often used with thicker material (such as dropouts), the integrity of the joint isn't compromised enough to worry about. In fact, some builders use brass while brazing lugs without problems.

Using flux while brazing is an absolute necessity. The primary purpose of flux is to protect the area being brazed from oxidation. Metals tend to react with air, and these reactions are accelerated with temperature. In the case of steel, oxidation can occur almost instantaneously, preventing the production of a sound brazed joint. Flux has the capability to dissolve oxidation, creating a protective atmosphere around the joint. Fluxes have a finite life span under heat, and brazing a dirty joint will exhaust the flux much faster. If the flux becomes exhausted, either because of an extensive heat cycle, an improperly prepared joint, or excessive heat, the filler material will refuse to run.

Fluxes are available in powder, paste and liquid forms. Paste flux is most commonly used by frame builders. In addition to paste flux, some builders like to use a liquid flux dispenser, especially when fillet brazing with brass. Such a system utilizes a third cylinder in the basic brazing setup filled with liquid flux. The flux travels through the acetylene line and directly into the flame. This keeps the joint especially clean, even through longer heat cycles.

Brazing With Lugs

A lug is a sleeve into which two tubes slide. They are then bonded to the lug with filler material (usually silver). A traditional lugged frame has four lugged intersections. These are the head tube/top tube, head tube/down tube, top tube/seat tube and bottom bracket. Although the bottom bracket isn't really a lug, a lugged bottom bracket does have sockets that receive the down tube, seat tube, and usually the chain stays, too. Lugged construction is the easiest method for most people to learn. The lugs act as their own fixturing system (which is not to say that a rigid frame jig is unnecessary), and this method is more tolerant of less-than-perfect fit. Lugged construction lends itself best to traditional designs, as the commercially available lugs aren't made in many varieties. The angles obtainable fall within a few degrees of each other, and the intended tube diameters don't stray far, either.

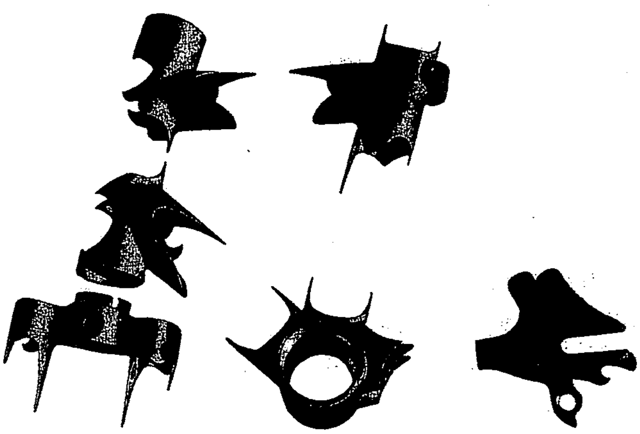


Fig. 7 - A typical lug set, including bottom bracket, fork crown and dropouts.

Lugs can be grouped in two classes, differentiated by their manufacturing process. The first, and probably most common are stamped lugs. A stamped lug is made from a sheet of steel that is deformed around a die to achieve the desired shape. Stamped lugs distinguish themselves by their rounded corners and fairly uniform thickness. Positive points of stamped lugs include low cost and easy formability. On the downside, they often require quite a bit of prep work before they are ready to be brazed, and their rounded edges create a sizable gap at the intersection of the tubes (figure 8). This gap can be difficult to fill, (in addition to being invisible to the builder) and therefore can compromise the strength of the joint.

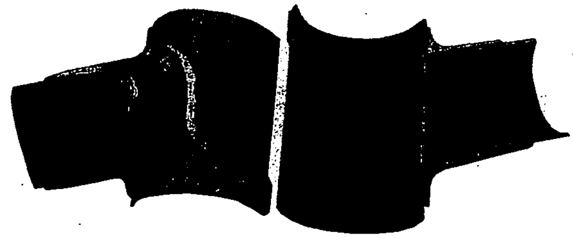


Fig. 8 - Cross section of a lugged frame joint after brazing

The second category of lugs is investment cast, sometimes called lost wax. Investment casting is a process that entails first molding a model out of wax, then investing the model with several layers of ceramic. The wax is then burned out of the ceramic, leaving a shell that can then be filled with molten steel. The finished lug has the advantage of being shaped exactly as the designer has intended it, without any gaps in crucial areas. Also, these lugs can be cast out of different alloys, and many high-quality lugs are made of chromoly. The only major downside of investment casting is the high cost involved.

The process of brazing a lug is simple. The whole joint is heated with the torch, and at the proper time filler material is added to one edge of the lug. Then, the heat is directed in such a way that the filler flows into the gap between the lug and the tube. Through a process called capillary attraction, the silver will flow toward the heat, even between closely spaced surfaces or against gravity. As more filler is added, it will eventually fill up the joint and appear at the opposite side of the lug.

Lugless Brazing (Fillet Brazing)

A high quality fillet brazed joint gives the illusion of one tube seamlessly blending into another (figure 9). Unfortunately, this is the most time consuming of all construction methods, and few fillet-brazed frames are available these days. This effect is accomplished by layering brass over the joint, then filing or sanding away any excess to leave a smooth radius between the tubes. These applications of brass, or fillets, can vary in thickness, but the amount of brass connecting the tubes must be at least three times as thick as the thinnest tube being joined in order to be sufficiently strong.

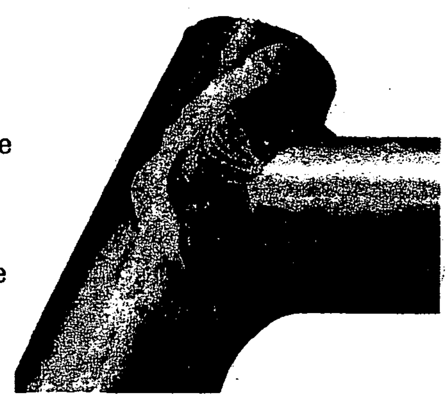


Fig. 9 - Fillet brazed joint.

The process of fillet brazing is similar to brazing with lugs, but with a few notable differences. First, as mentioned above, brass is used rather than silver. Therefore, more heat is directed into the joint, so tube selection may need to be adjusted. Some of the problems associated with lugged construction are alleviated by fillet brazing. Most important, the builder is no longer limited to a tight range of angles and tube dimensions. Although repair is not as simple as with lugged frames, fillet brazed frames are still repairable.

TIG Welding

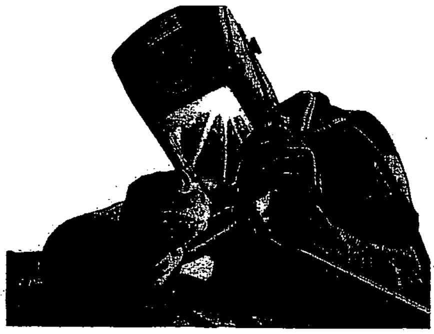


Fig. 10 - A UBI student TIG welds a bike frame.

Tungsten Inert Gas (TIG) welding is an arc fusion process in which intense heat is produced between a non-consumable electrode (tungsten) and the work piece. An inert gas, most frequently argon, is used to provide a shield to protect the welding zone from atmospheric contamination and oxidation. The TIG welding process has the advantage of being able to work on any electrically conductive metal. When TIG welding aluminum, your power supply must provide AC power. DC is appropriate for all other metals.

To produce a good weld, TIG requires good joint fit and the base metals must be very clean. They are stronger, more ductile and more corrosion resistant than welds made with ordinary metal arc welding methods. Since no flux is needed, the entire welding operation takes place without spatter or sparks. Therefore, no post weld cleaning operations are necessary. Filler material is manually fed, similar to oxy-acetylene brazing. Unlike brazing, however, the filler material is either identical or nearly identical to the parent metals. Choosing a correct filler metal is imperative, as it will be melted along with the parent material, effectively creating a new alloy in the weld zone.

TIG Welding Equipment

It has been mentioned earlier that a good TIG setup requires a significant investment. Whereas brazing equipment costs only a few hundred dollars, a high quality TIG welder with all the necessary accouterments costs at least two thousand dollars. If you are planning to build a lot of bikes, however, the equipment will easily pay for itself by the time saved.

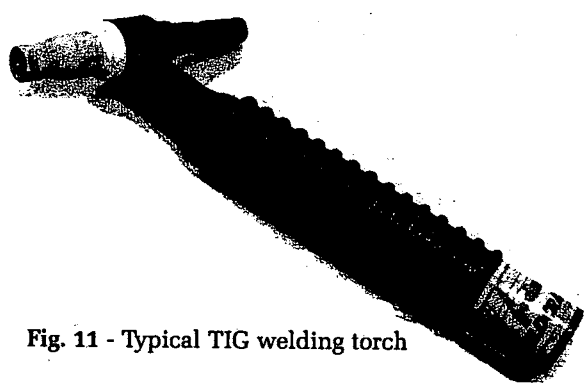


Fig. 11 - Typical TIG welding torch

The main unit of a TIG outfit includes a power source, furnishing between 90 and 250 amps of power, and a snap start unit, which serves to initiate the arc. The power source is connected to the torch cable, which can be either water or air cooled. The torch itself isn't much larger than a pencil, which allows for the high degree of control needed to produce clean, smooth welds. The torch has a collet, which holds the electrode, and sometimes a gas lens, which directs the flow of the shielding gas. Another optional component is a pulser. The pulser controls the current traveling through the circuit by forming it into waves. Various settings on the pulser affect the depth of penetration of the weld, the intensity of the power, and the cosmetics of the weld bead.

TIG Welding Materials

By definition, the only consumable materials needed for TIG welding are filler rod and shielding gas. In reality, tungsten electrodes can be added to that list. The electrode material used for TIG welding is usually tungsten or tungsten alloyed with thorium or zirconium. Tungsten has the highest melting point of any metal, (6170°F), which makes it ideal for welding purposes.

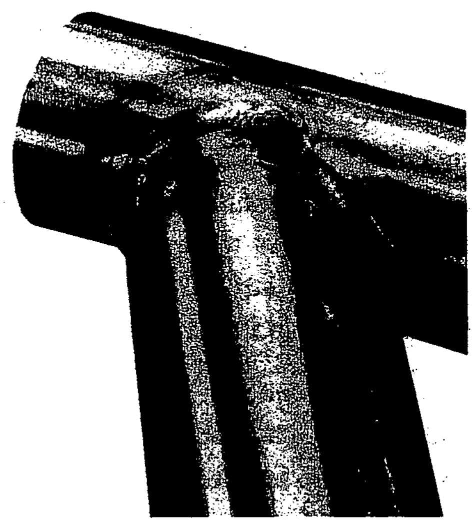


Fig. 12 - A typical TIG welded joint.

The makeup of filler material for TIG welding has been hinted at earlier, but it deserves a closer look. Generally, the composition of the filler material should match that of the parent material. In the case of chromoly steel, however, that would be a serious mistake. Due to post-weld cooling characteristics of chromoly, the chromoly filler tends to draw away from the tubes being joined, causing fractures in the weld. An easy solution is to use mild steel filler rod, which has more acceptable cooling characteristics.

Although any inert gas would work, the only shielding gases used for TIG welding are argon or helium, or a mixture of the two. For bike building, argon is most appropriate. Helium is generally used only when a hotter arc is needed, for example when welding significantly thicker material.

Carbon Fiber Construction

Carbon fiber bikes have been prevalent in the bike industry for many years, but carbon fiber frame construction is still constantly evolving. Early carbon fiber frame construction was a process of bonding round carbon tubes to metal lugs, generically called adhesive bonding (described in more detail later in this chapter). This process yielded a weight reduction over full metal construction. In the early to mid 1990's, a few manufacturers started developing full carbon fiber frames. This was done using the same adhesive bonding construction, but the lugs were constructed from carbon fiber. This resulted in a lighter weight frame with a more supple ride characteristic. With full carbon fiber frames the damping properties of the material were more fully realized. Frames are still being constructed using lug and tube adhesive bonding.

For example, tubing manufacturers such as Dedacciai and Columbus offer carbon fiber lug and tube sets. This allows even small custom frame builders to offer carbon frames.

Around 2000, more manufacturers started to use what is marketed as "monocoque" frame construction. This process uses large molds to create the front triangle of the frame. Carbon fiber sheets are cut and layered in a very specific orientation, called a lay-up schedule, within the mold. The lay-up schedule (or orientations of the carbon sheets) is determined by the ride characteristics the design engineer is wanting from the bike. The compliance,stiffness, weight, strength, and type of carbon are all directly related to the lay-up schedule. Once the carbon fiber is in the mold, the assembly is heated. The heat binds the layers of carbon fiber with an epoxy matrix to form a solid structure. During this process the carbon fiber is being pushed outward into the mold by a pressurized core medium (bladder or foam core), creating the desired shape. The rear assembly of the frame can be made the same way. The pieces are then bonded together to create a very light, specifically tuned frame. Unlike the tubing and lug method of carbon construction, monocoque manufacturing is more suited to large-scale companies with significant amounts of capital to invest, because it requires extensive infrastructure. A single mold for a single size and model of bike can cost tens of thousands of dollars.

Bladder or foam core monocoque construction has some limitations. With bladder or foam construction the finished shapes tend to be more curved or "organic." This is because they require more carbon in transition spots. More carbon fiber must be laid in the mold in areas where the bladder or foam cannot properly compress. Further, bladder or foam construction cannot adequately mold tight angles such as a true 90° angle.

A new method, very similar to molded monocoque construction, has addressed some of these limitations, and is allowing manufacturers to push the limits of weight. The latest method of construction in the bike industry, sometimes called "net molding," uses a rigid material as a core in the molds, instead of a bladder or foam core. This material melts away at a temperature just below the curing temperature of the frame.

By using a rigid material for the core, less carbon fiber can be used than with bladder or foam construction. And because the material melts out of the frame there is no residual material left inside. The resulting frame is lighter than an equivalent frame made with bladder or foam core construction. The rigid material also allows for very specific dimensions and angles to be molded into the frame. Manufacturers are using this trait to further reduce weight by creating precise dimensions within a frame at the bearing points. With this method, no longer does a bottom bracket or headset require cups that are pressed or threaded - cartridge bearing are simply placed directly into the frame. The result is a further reduction in weight. This method of construction is allowing for sub 900g frames, unheard of a few years ago. Despite this, many in the industry feel that carbon fiber bike frame construction is still in its infancy.

Adhesive Bonding

There are a few reasons why a manufacturer might choose to bond frames together rather than brazing or welding them. For example, if two dissimilar materials are being joined, such as aluminum and steel, they will not coalesce with brazing or welding. Or, the material being used may not be able to be fused by heat at all, as is the case with carbon fiber. Finally, certain materials lose a significant amount of their integrity with welding, such as certain aluminum alloys.

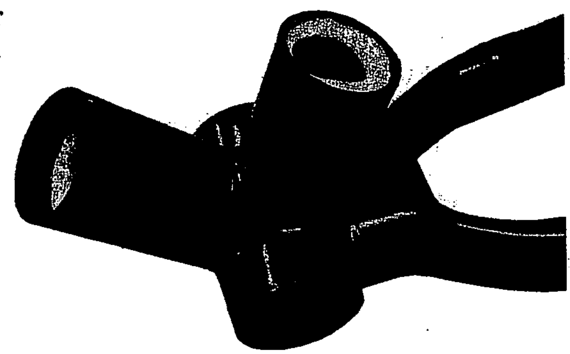


Fig.13 - Bonded construction: carbon tubing with aluminum BB shell.

Simply put, bonding is a way to "glue" frame members together. Usually, an internal lug is used, one in which the tubes slip over the lug. A thin layer of epoxy is applied between the lug and the tube. Once this process is applied to each frame joint, the frame may be heated to set the epoxy. The excess epoxy is then sanded off, creating a smooth, seamless appearance.

Another common application of bonding is to join carbon fiber frame assemblies, such as rear triangles, to main frames constructed of steel, titanium or aluminum.

FRAME PREP AND ALIGNMENT

Bicycle frames commonly are constructed by welding or brazing metal tubing together, which involves the application of considerable heat at the junctions of the frame tubes. Heat can cause the frame material to distort, resulting in frame tubes that are not perfectly round, and/or in frames that are not perfectly straight. Also, paint, welding material and other contaminants can find their way into various parts of the frame during construction. To compensate for the effects of these imperfections introduced during frame building, a frame preparation should be done before it is assembled into a complete bike.

The process of frame preparation and alignment ensures that all bearing surfaces are parallel, the frame's threaded parts (bottom bracket shell, fork steerer tube, derailleur hanger, etc.) are clean and ready to accept components, and the head and seat tubes are perfectly round. Not only does a carefully prepared frame ride better, it also allows maximum life for bearing assemblies and allows for a faster and more trouble-free assembly.

There are three main types of procedure used in preparing a frame: chasing threads, facing frame tubes, and reaming frame tubes. In chasing, a cutting tool is utilized to clean the threads on the frame's bottom bracket shell, rear derailleur hanger, fork steerer tube (if the frame utilizes a threaded headset), water bottle bosses, and so on. Clean threads allow for easier mounting of components and lessen the chance of cross-threading.

In facing, a different type of cutting tool is used on the head tube and bottom bracket shell and the disc brake tabs to make the ends of each tube parallel with each other. This assures proper alignment of the bearings, especially crucial for headsets and for adjustable cup bottom brackets.

It is usually necessary to ream the head tube and seat tube. When a frame is built, the heat applied to the tubes by brazing or welding can distort them, causing the tubes to become slightly ovalized. If the head and seat tubes are not returned to roundness, installing headsets and seat posts can be difficult. In some cases, headset cups installed in un-reamed head tubes can warp, resulting in poor bearing alignment and even binding.

Machine Tool Fundamentals

Specialized metal cutting tools are necessary for proper frame preparation. These tools remove metal from the work piece (in this case, a bike frame) by producing tiny chips, rather than the long curls you might associate with wood cutting tools. In order for these chips to be cut without damaging the frame or the tool itself, some basic machine tool fundamentals must be followed. These include proper tool selection, rigid work piece and tool fixturing, proper assessment of the material to be cut, proper tool speed and feed rate, use of coolants or lubricants, and attention to surface finish.

In general, the tools required for bicycle frame prep include taps, dies, mills, and reamers. Taps are used for chasing existing internal threads (such as inside the bottom bracket shell), or for cutting new threads. Dies perform the same function, but for external threads, such as you would find on a threaded fork steerer tube. Mills cut smooth, flat surfaces or faces. Reamers are used to produce smooth, round internal surfaces, such as inside the head tube or seat tube. Choosing the correct type and size of tool for the job is vital for proper frame prep.

Once the correct tool is determined, proper fixturing of the work piece and the tool itself are essential to a successful machining operation. Most machine shops achieve this by using heavy machinist vises and massive, power-driven machines. However, most bike shops are equipped with nothing stouter than a Park repair stand and a small vise, and many of the difficulties associated with bike frame prep can be traced to this relatively flimsy fixturing. Repair stands flex quite a bit, and this can cause cutting tools to chatter, creating an uneven finish. To minimize this problem, you should clamp the frame as close as possible to the area to be machined, and as firmly as possible without damaging the frame's finish. Once you begin the machining operation, the tool's handles should be held as securely as possible.

Steel, aluminum and titanium are the most typical metals used to manufacture bike frames. These metals usually contain alloying ingredients that can affect the outcome of the frame prep procedure. In the following discussion, we will assume low alloy steel as the material being machined.

Three variables greatly affect the quality of the surface finish and the longevity of the cutting tool. These are tool speed, tool feed, and lubrication. Tool speed refers to how fast the tool is rotating during the procedure. Tool feed is the pressure exerted on the tool and therefore on the work surface. The speed and feed rates published in machinists' guides, handbooks and text books all assume a rigid fixture and a power driven tool, so they are not a useful guide for frame prep hand tools.

Metal cutting fluids should always be used with these hand cutting tool operations. Most multi-purpose fluids are acceptable.

The bike frame will generally be held in a Park repair stand during the prep procedure. The lack of rigidity inherent in this set-up can lead to a "chattered" finish from milling and reaming. Whenever chatter becomes a problem, the best remedy is to decrease cutting tool speed: in other words, turn the tool more slowly. Too little or too much feed rate (pressure on the cutting tool) can also lead to a poor finish. To determine the best feed rate, gradually increase the pressure on the cutting tool until a small chip is produced by the cutting edge. Try to maintain this pressure throughout the procedure. With these fundamentals in mind, the goal of the cutting procedure is to produce smooth, clean, machined surface. Chatter marks or galling are unacceptable!

The order of frame prep typically begins with chasing and facing the bottom bracket shell, followed by reaming and facing the head tube. The seat tube is then reamed or honed if needed. Next, small taps are used to chase the threads in any braze-on eyelets, bottle cage mounts, cable stops and the derailleur hanger. If a threaded fork will be used, the steerer tube threads should be chased, and, if necessary, the fork crown race seat is faced to insure proper headset bearing alignment. With the decline in sales of threaded, welded, or brazed forks, these last procedures are often unnecessary.

The bottom bracket shell is prepped to reduce the effects of distortion caused by heating the shell during frame construction. This distortion usually takes two forms. First, the shell may be slightly ovalized, which will impair easy installation of the bottom bracket assembly. Second, the faces of the shell may not be exactly parallel, which will degrade the performance of the bearings.

Heat is not the only problem. The threads of the bottom bracket shell may become contaminated with flux, brazing filler, or over-penetration of welds, so they must be cleared of this material. Also, excess paint can contaminate the threads and coat the faces of the shell unevenly, and must be removed. When preparing the bottom bracket, begin by chasing the threads. This is to prevent damage to the threaded guides used by most bottom bracket facing tools.

Before using chasing tools, it is critical to determine what kind of bottom bracket thread spec is on the bike. While the brand and country of origin of the bike may provide some clues to the type of shell, do not guess. For information on identifying bottom bracket thread specifications see chapter 3 of this manual, or Sutherland's Handbook, 7th Ed., page 4-2.

STUDENT HANDS-ON:

Chasing Bottom Bracket

Tools needed:

- Park BTS-1 BB threading/chasing tool
- Cutting fluid

Step 1 - Select a chasing tool and install the correct taps onto the handles. Taps MUST match the thread standard on the BB shell. Reference Chpt 3, Pg 3-19.

Step 2 - Inspect the inside of the bottom bracket shell for any obstructions. Anything that protrudes beyond the thread profile should be removed by careful filing. Do not try to remove any of these protrusions with the tap! This could damage the tap, the frame, or both.

Step 3 - Apply cutting fluid to the inside of the BB shell, and to the outside of both taps.

Step 4 - If tapping an ISO or English threaded BB, verify that the left-hand threaded tap is on the drive side of the frame.

Step 5 - Insert the tap handle pilots through the BB shell and engage them. Gently center the taps in the BB shell.

Step 6 - Thread the taps inward three to five turns by simultaneously turning the handles in the appropriate direction.

Step 7 - Tap only one side at a time by slowly turning the tap into the frame to its full depth. If heavy resistance is felt at the handles, first verify that the proper tap is being used on the correct side of the frame. Taps should never be forced! But moderate resistance is normal on a frame that has never been prepped.

A conservative approach is to turn the tap inward one or two turns, then back it out 1/4 - 1/2 of a turn. This allows the cutting fluid to flow back onto the cutting edges, while clearing the metal chips into the flutes of the taps.

Step 8 - After you have finished tapping one side of the shell, back the tap outward about half way, and begin the second side. This allows the second tap to go into the shell to its full depth without bottoming out on the first tap.

Step 9 - To remove the taps, back them both out of the threads. The pilots should still be engaged. Next, simultaneously pull both taps away from the BB shell.

Step 10 - Clean the BB shell with a bottle brush and rag, and inspect your work. Shiny areas indicate where metal was removed and will provide some insight as to how distorted the threads were.

Step 11 - Clean the taps thoroughly, making sure there are no metal chips remaining in the tap threads. Store the taps and handles as directed by your instructor. Have your instructor examine your work. If acceptable, the instructor will sign your Student Daily Checklist.

Facing the Bottom Bracket Shell

This procedure will enhance bearing performance by machining both sides of the bottom bracket shell so that they are parallel to each other and perpendicular to the bottom bracket axis. Most distortion is usually encountered near the bottom bracket-chain stay joint.

STUDENT HANDS-ON:

Facing the Bottom Bracket Shell

Tools needed:

- Park BFS-1 BB facing tool
- Cutting fluid

Step 1 - Select a tool. The following instructions are for the Park BB facing set only.

Step 2 - Install the threaded guides on both sides of the shell, and engage them a couple of turns. They should thread in easily because you just chased the threads in the previous hands-on! Using the BB facing handle (without the facing mill), finish threading the guides into the shell. An optimal position for the guides is about two turns inside the shell. This allows adequate clearance so that the mill won't hit the guides. Consider using the stop spacer.

Step 3 - Install the shell facing mill on the handle.

Step 4 - Insert the guide for the mill into the threaded guides in the bottom bracket. The mill should not quite touch the shell yet.

Step 5 - On the opposite side of the shell from the mill, install the large knurled spacer on the guide (The guide should be protruding from the shell). Slide the keyed washer onto the guide. After the washer, slide the feed spring on, and secure the entire assembly by screwing the tension adjusting knob onto the guide. Do not turn the tension knob farther than necessary to secure the washer, spring and spacer.

Step 6 - Engage the mill cutter face with the bottom bracket shell by gradually increasing spring tension.

Step 7 - Once the mill touches the edge of the BB shell, turn the handles slowly and smoothly only in a clockwise direction. Slowly increase the spring tension by turning the tension adjusting knob about 1/4 of a turn, then continue to slowly turn the handles. If the shell has never been faced, you will notice the paint being removed first. As mentioned before, the chainstay-bottom bracket joint is likely the location of the most heat distortion. After the mill has cut through the paint, you will notice shiny areas on the edge of the BB shell as material is removed. A typical amount of material to remove is .1 - .3mm per side. Removing more than .5mm per side is not recommended.

Step 8 — Have an instructor check your work. If it passes inspection, the instructor will sign your Student Daily Checklist.

Head Tube Facing and Reaming

As with the bottom bracket prep, head tube facing and reaming is done to compensate for heat distortion from the frame's fabrication. Facing ensures that the bike's headset bearing assemblies are parallel to each other. Reaming the headtube restores it to roundness, which will allow the headset cups to be pressed in without distorting them.

Before we ream or face the head tube we must determine the headtube and headset standard to be used on the bike. There are three common head tube sizes in use, 1", 1-1/8", and 1-1/4". A new 1-1/2" head tube standard is being used by some downhill bikes, but this has yet to see wide acceptance. To determine the headtube diameter being used, an easy indirect method is to measure the steerer tube of the fork that will be used with the frame. It will be either 1", 1-1/8", or 1-1/4".

Once these measurements are made, you can choose the correct cutting head for the head tube reamer.

In this procedure, the reaming and facing cutters are mounted on the same tool. The reamer enters the head tube first and after it's done its job, the facer contacts the head tube and begins cutting.

STUDENT HANDS-ON:

Head Tube Facing and Reaming

Tools needed: Park HTR-1 Head tube facing/ream tool Cutting fluid

Step 1 - Install the proper reamer on the head tube reamer/facer.

Step 2 - Clamp the frame as close to the head tube as possible while leaving enough clearance for the handles to rotate. The head tube should be vertical.

Step 3 - Apply cutting fluid to the reamer/facer and to the inside of the head tube.

Step 4 - Hold the centering cone into the opposite side of the head tube, and pass the reamer/facer pilot through the cone while depressing the tension knob. This will ensure that the reaming cutter is brought gently and squarely into contact with the head tube.

Step 5 - Hold the handles firmly to provide some vibration damping. Turn the reamer clockwise. Do not try to speed up the reaming process by adding force to the handles. Sufficient cutting force is being provided by the tension spring! As with the BB facer, the head tube reamer will begin cutting with little spring force as long as the tool is sharp. As you ream deeper into the head tube, you will lose spring tension, so continue to compensate by tightening the tension knob to maintain contact with the head tube.

Step 6 - After the facer has reached the head tube, stop adding spring tension once enough force has been established to start cutting a chip. Continue facing until a smooth, machined surface is produced. You typically need to face off .1 - .25mm per side of the head tube.

Step 7 - After completing one side of the head tube, turn the bike over in the stand so the unfaced side of the head tube is pointing up. Repeat steps 3-6 for this side.

Step 8 - Deburr the sharp inner edge of both sides of the head tube. Clean the inside of the head tube and the frame itself with a rag and some rubbing alcohol. Some cutting fluids can harm the frame's finish.

Step 9 - Clean and store the head tube reaming/facing set. Have your instructor examine your work. If acceptable the instructor will sign your Student Daily Checklist.

ADDITIONAL FRAME PREP PROCEDURES

Many frame prep operations include the use of hand taps to clean the threads on all remaining fittings, such as the water bottle bosses, derailleur hanger, threaded cable stops for barrel adjusters, rack mounts, etc. As with other aspects of frame prep, using these small hand taps to clean up the threads on the frame's fittings will speed the installation of the bike's components. However, hand taps can do more harm than good if used improperly. Make sure that you have absolutely identified the correct thread specification before cleaning any threads with a hand tap. The table below lists some common thread specifications.

Thread	Application
M5x.8	Water bottle bosses, fender/rack eyelets, down tube shift bosses, some barrel adjusters, plastic bottom bracket cable guides
M6 x 1	Cantilever brake bosses, some barrel adjusters
M10 x 1	Most derailleur hangers
M3 x .5	Dropout adjuster screw

When tapping blind holes, such as older down tube shift bosses and closed water bottle bosses, a bottoming tap should be used to prevent the tap from running into the frame tube. Otherwise, any general use tap that is the correct thread specification should be fine.

Another important frame prep step is facing disc brake mounts. Proper disc brake performance requires that the caliper align perfectly with the disc. Magura and VAR both make facing tools that mount in the dropouts of either the frame or fork and hold a cutting tool that will face a standard ISO disc brake mount. This ensures that the caliper mounting surface is square with the disc. These tools also come with adapters to be used on forks with 20mm through-axles.

A typical final step in prepping a steel frame is to use a metal preservative or protectant like Frame Saver or LPS3 on the inside of the frame tubes. This is usually sprayed into any and all frame openings like the seat tube, head tube, vent holes, water bottle bosses, etc. This guards against corrosion caused by the infiltration of water and other contaminants into the frame. If you use one of these protectants, be sure to clean up any overspray or drips that get on the bike's painted surfaces.

One final note on all frame prep procedures: A mistake in tapping, reaming, or facing can ruin an expensive frame. When in doubt about a procedure, contact the manufacturer first!

ADDITIONAL READING ABOUT SUSPENSION FORKS, FRAME MATERIALS AND FRAME CONSTRUCTION

The purpose of this list is to provide some alternate sources to help you learn the material covered in class. These reference materials may be checked out from the office for overnight or weekend use and returned the following morning. There is no requirement to do any of this reading. Read as little, or as much as you would like.

Sutherland's Handbook for Bicycle Mechanics (6th Ed):

Suspension Forks and Frames, 15 - 1 through 15 - 55

Sutherland's Handbook for Bicycle Mechanics (7th Ed):

Forks and Frames, Chapter 14

Bicycle Technology

Materials and Construction, Pages 43 through 58

The Frame, Pages 59 through 74

Web Resources:

Cannondale: www.cannondale.com/innovation

DT Swiss: www.dtswiss.com/forks

Foes Racing: www.foesracing.com/

Fox: service.foxracingshox.com

Magura: www.magura.com/en/products/

Manitou: www.manitoumtb.com

Marzocchi: www.marzocchi.com

Push Industries: www.pushindustries.com

Risse Racing: www.risseracing.com

Rock Shox: www.rockshox.com

White Brothers: www.mountainracingproducts.com/white-brothers

Sheldonbrown.com: "Frame Materials for the Touring Cyclist"

www.sheldonbrown.com/frame-materials.html

Craig Calfee and David Kelly: "Technical White Paper" (carbon fiber)

www.calfeedesign.com/tech-papers/technical-white-paper

Scot Nicol: "Metallurgy for Cyclists"

www.strongframes.com/more_stuff/materials_tech/metallurgy

Cyclingnews.com: "Frame Alignment"

www.cyclingnews.com/tech/fix/?id=frame

Park Tool: "Bottom Bracket Tapping, Threading, Chasing and Facing"

http://www.parktool.com/blog/repair-help/bottom-bracket-tapping-and-facing-bts-bfs

"Head Tube Facing and Reaming"

http://www.parktool.com/blog/repair-help/headtube-reaming-and-facing

"Fork Crown Machining"

http://www.parktool.com/blog/repair-help/crown-race-machining

CHAPTER 8 APPENDIX

SEAT TUBE REAMING

The objective of this procedure is to make adjusting the seat post easy with no galling or scratching of the post when it is moved, and to secure the post with minimal torque on the seat binder. The following steps will guide you through using a reamer on the seat tube.

HOW TO

Reaming the Seat Tube

Tools needed:
Seat tube reamer
Cutting fluid

Step 1 - Select the appropriate reamer for the seat tube size on the frame. Secure the frame in a repair stand. The best position for the frame is for the seat tube to be roughly horizontal, with the BB slightly higher and the seat tube slot facing up. This minimizes the tendency of the reamer blades to snag on the slot and prevents metal chips from falling into the BB shell. But most importantly, if you lose the handles of the reamer while you're cutting, the reamer won't fall into the seat tube! Lodging a reamer in a seat tube is a really unpleasant problem to fix.

Step 2 - Establish a good starting diameter for the reamer. It is difficult to precisely measure the effective cutting diameter of an adjustable reamer. Also, the amount of distortion present in the seat tube is unique to each frame. So the best way of establishing a starting point is by feel, rather than by any set formula. Begin by moving the blades down the reamer body, away from the handle, until the reamer can slip easily into the seat tube and be rotated freely without removing any material.

Step 3 - Once you've established a starting point, remove the reamer from the seat tube. Gradually expand the reamer blades by moving them up the reamer body. This is accomplished by moving the upper adjusting nut toward the handle, and then moving the lower adjusting nut toward the handle. This pushes the blades against the upper adjusting nut and expands them outward. NOTE: The adjusting nuts should hold the blades firmly. Make sure the nuts are snug! One full turn of the adjusting nuts will expand the cutting diameter by approximately .005" (.1mm).

Step 4 - Make sure the binder bolt is supporting the seat tube slot, but is not compressing it (or you will remove too much material around the top of the seat tube). Spray cutting fluid on the reamer blades and the inside of the seat tube. Find the orientation of the reamer that allows it to slip into the seat tube without cutting. Begin turning the handles clockwise. You will feel metal being removed from areas where the tube has been distorted. Once you have removed all the metal at that setting (the reamer turns without cutting), remove the reamer and expand it 1/4 to 1/3 of a turn.

Step 5 - Before continuing with the reaming process, check the fit of an appropriate size seat post. If the post can be adjusted easily without scratching and can be clamped securely with the binder bolt, no additional reaming is necessary. However, if the post is too tight, repeat step four as many times as necessary, each time expanding the cutting blades about 1/4 to 1/3 turn, and then checking the fit of the seat post.

Step 6 - Clean up any minor burrs and paint with a Flex-Hone® if necessary. This is sometimes used as a final operation after reaming. Flex-Hone® operation is pretty straightforward. Choose the correct size hone, lube it with oil, and run it down the inside of the seat tube with a hand drill at medium speed. Do not remove the hone while the drill is running or you'll splatter the immediate surroundings (including yourself) with oil and metal flakes.

Step 7 - Remove any excess oil from the frame. Clean and store all tools.

FORK PREP

Fork prep procedures are rarely called for in modern service departments, primarily due to the popularity of suspension forks on mountain bikes and carbon forks on road bikes. The crown race seats on suspension forks, carbon road forks, and glued or pressed forks are machined before assembly and not heated enough to cause significant distortion. So the crown races on these types of forks do not need to be milled before assembling the bike. Threaded headsets are increasingly rare on higher end bikes, so the need to chase steerer threads usually arises in repairing an older bike, rather than prepping a new bike.

A properly milled crown race seat provides the correct press fit for the headset crown race, as well as a flat platform or "seat" that is parallel to the adjustable race at the top of the head tube. This is essential for the headset to rotate smoothly without binding.

Steel forks that have been brazed or welded will have some distortion of the crown race seat. In some cases the manufacturer may have already re-machined the fork, but most often a new steel fork will require some prep work. Aluminum distorts severely when welded, so most manufacturers correct this as part of the production process. If the fork has not been in service, a good rule of thumb is to assume that a new welded or brazed steel fork should be milled, and an aluminum or carbon fork will not require any milling. Again, when in doubt, contact the manufacturer.

If a fork has been in service, you can determine whether the fork needs prep work by checking the ball track of the headset. The uniformity of the ball track on the crown race will be a direct reflection of the amount of distortion of the crown race seat. If you find an uneven wear pattern, the fork crown should probably be milled, assuming the headset was otherwise installed correctly.

HOW TO

Milling the Fork Crown Race Seat

Tools needed:

- Park CRC1 crown race milling tool
- Cutting fluid

Step 1 - If it's been determined that milling is required, make sure a crown race cutter of the correct diameter is available. For most 1" and 1-1/8" head sets, the crown race cutter produces a crown race seat that is .1 mm (.004 in.) larger than the crown race itself. See Sutherland's 7th Ed., page 12 - 6 for any variations.

Step 2 - Once the correct mill has been installed on the guide and handles, the process is much like facing the BB shell. Clamp the fork in a vise, and lower the crown race tool onto the top of the crown race. Apply cutting fluid to the tool and the crown race seat. Turn the handles clockwise only and remove a minimum amount of material to produce a clean cut all the way around the race seat.

The guide system on the Park CRC1 uses an adjustable double angle collet that compresses just enough to center itself around the steerer tube and still turn freely. The "feed," or cutting force, is controlled by hand pressure. Other brands such as VAR and Campagnolo use a feed spring and tension knob assembly to apply cutting force. However, these work only with threaded steerers long enough to accommodate these additional parts.

Step 3 - Clean any remaining cutting fluid from the fork and tool. Carefully store the crown race cutter.

HOW TO

Chasing Fork Threads

Tools needed:
Park CRC1 crown race milling tool
Cutting fluid

As mentioned before, chasing threads on a fork steerer tube has become a fairly rare procedure. However, slight thread damage due to improper headset installation, adjustment, or lock washer rotation may be occasion to use a fork column die. UBI recommends using fork column dies to chase threads only. Cutting new threads on a fork is a last resort only, and presents potential liability problems. Most threaded steerers have 50- 60mm of thread. Cutting new threads beyond this could allow the stem expander wedge to crack the steerer.

Step 1 - As with previous cutting tool operations, the first step is to identify the manufacturer's thread spec. Most threaded 1" steerers have 24 TPI, and almost all 1-1/8" steers have 26 TPI. For exceptions, see Sutherlands, Sixth Edition, page 14 - 2, 3.

Step 2 - Load the correct die into the handle/guide assembly.

Step 3 - Apply cutting fluid to the die and the fork's threads. Center the guide over the steerer and carefully thread the die down onto the threads. It is very important that the guide is centered so the threads will be chased without damage.

Step 4 - After chasing the threads, clean any remaining cutting fluid from the fork. Clean and store the fork die.

Chapter 9

Bike Fit, Pedals, Stems, Handlebars, and Bicycle Overhaul

Objectives:

- Understand the different steps of proper bike fit
- Understand frame sizing
- Understand stem/handlebar sizing and compatibility
- Perform detailed steps of a bicycle overhaul

Professional bike fitting is one of the fastest growing segments of the bike industry. Professional fitters often combine backgrounds in sports medicine, physical therapy, and coaching to provide clients with a comprehensive fit tailored to their specific needs. These fittings may incorporate the use of sophisticated motion-capture software, and can span several sessions. As such, professional bike fitting has almost become an industry in its own right, complete with competing philosophies and divergent approaches. Several companies offer extensive training in their particular fit system, as well as specialized fitting tools. At times these systems can present contradictory recommendations. This can make achieving proper bike fit seem daunting to the novice. The goal of this chapter is not to espouse any one bike fit philosophy, nor will it serve to replace the years of study and hands-on experience characteristic of successful professional fitters. What it will do is define the parameters and approaches common to the different fit systems, as well as provide you with the baseline of knowledge necessary to help you navigate proper bike fit in the shop environment.

Achieving proper bike fit is essential not only for the comfort and efficiency of the rider, but also to prevent injury. An ill-fitting bicycle can place undue stress on the rider's joints and musculature, and in extreme cases can cause long-term physical damage. Preventing injury should be the primary concern of the fitter, whether it be the professional in the fit studio, or the shop mechanic setting a bicycle up for a test ride on a busy Saturday morning. Additionally, a bicycle that does not fit the rider will not handle as designed, making it potentially unsafe to operate.

Determining proper fit for a given rider begins with assessing the intended use of the

bike. For any one rider there may be one or more correct fits, depending upon whether the goal is maximizing efficiency, comfort, aerodynamics, or a combination of these three elements. Suitability for a particular discipline will also affect what is considered proper fit. A fit that is appropriate for a track racing bicycle would be ill-suited for long-distance touring. Similarly, downhill racing places different demands on the bike and rider than does cross-country racing, resulting in two distinct fits.

Bike fit is not a static set of parameters. It may vary slightly throughout the year, or throughout a rider's cycling life. Colder weather can reduce flexibility, resulting in a winter riding position that may be slightly more upright. Additional layers of clothing may prompt a rider to lower the saddle height to compensate. As a novice rider adapts to cycling and the rider's flexibility improves, the position on the bike may evolve. For this reason many fitters avoid simply entering a series of body measurements into a formula to arrive at a universal, "ideal" fit. Two riders with the same measurements may have different levels of fitness, flexibility, and styles of riding. The pre-fitting interview can be as important as other factors in determining the final fit.

This chapter is not intended to provide specialty fit training. Rather, the goal is to give you an overview of the many variables that must be considered in any bike fit.

THE FRAME

Common to all fit systems is to first determine the proper frame size for the rider. The frame is the foundation on which proper bike fit is built. Many elements can be adjusted around the frame in order to fine-tune the fit. These include stem length and rise, saddle position, crank length, cleat position, handlebar design, and the position of the control levers, just to name a few. But there are limitations to how these variables may be manipulated in order to adapt the rider to a given frame size. If a frame is simply too large or too small, there will be unavoidable compromises in handling and comfort that may compel the novice to abandon cycling completely.

In order to determine proper frame size it is necessary to first understand the different ways in which manufacturers may describe the size of a frame. Most manufacturers produce frame geometry charts identifying the dimensions of the frame in a table sorted by size. The interplay of the length of the various frame tubes and the angles between them affects not only the fit of the bicycle, but also the handling characteristics and road feel. Learning how to decode the angles and measurements in a typical frame geometry chart will help you determine whether a given bicycle is appropriate for the intended use. As an example, the typical touring bicycle is designed to be comfortable even after long hours in the saddle, is somewhat compliant, and stable at higher speeds when fully loaded. Such a design requires more rider input in order to change direction, making touring bikes naturally less maneuverable. A road racing

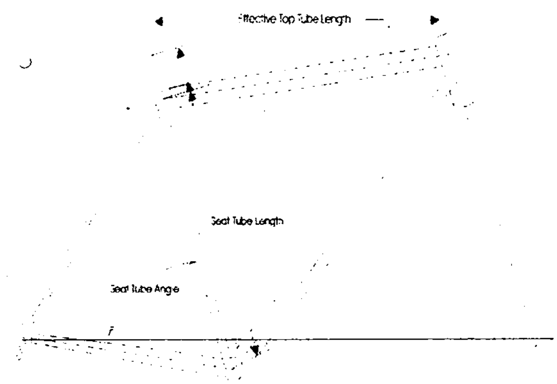


Fig. 1

bicycle designed for criterium or circuit racing, in contrast, should be stiff, efficient, and nimble. This results in a bicycle with high maneuverability, but potentially one that is less comfortable over long distances.

Frame Sizing

Frames sizes have traditionally been described in terms of the length of the seat tube. How the seat tube length is measured, however, varies widely among manufacturers. All manufacturers use the center of the bottom bracket as the starting point for the seat tube. The length of the seat tube may be identified variously as the center of the top tube/seat tube junction, the top of the top tube/seat tube junction, or the actual top of the seat tube where the seat post enters the frame. As a result, it is important not only to know the seat tube length of a given frame, but how a particular manufacturer identifies the length. A 54cm road bike from one manufacturer may be identical to a 56cm road bike from another, even though the actual lengths of the seat tubes may be the same.

Complicating this lack of standardization is the fact that most frames no longer have a horizontal top tube. Traditionally, frames utilized a top tube that was horizontal, or parallel to the ground. With this design, top tube length is proportionate to seat tube length: the longer the seat tube, the longer the top tube, and thus the greater the reach of the bike. With a horizontal top tube design, the length of the seat tube also determines the stand over height of the bicycle. This can present challenges to riders who may have shorter legs relative to their torso and arms. In order to achieve proper reach (a function of top tube length) the rider may have to choose a frame whose seat tube is too long to provide adequate stand over clearance. This is potentially unsafe.

In recent years, frames utilizing sloping top tubes, often called "compact geometry", have become more prevalent. Compact geometry presents several advantages to both the manufacturer and the rider. From a manufacturing standpoint, the most obvious benefit is the ability to accommodate a wider range of riders with fewer frame sizes. Eliminating the direct correlation between stand over height and top tube length means that manufacturers can offer "T-shirt sizing": Small, medium, large, and extra-large, instead of the more traditional 2cm increments. Additionally, compact geometry requires less material, making the frames lighter and stiffer. This lighter, stiffer, stronger frame can be a benefit to the rider. Compact geometry allows the rider to choose a frame based upon the reach without compromising stand over clearance. Manufacturers who use sloping top tube designs may describe the seat tube length as the point at which the seat tube would intersect a hypothetical horizontal top tube. This hypothetical horizontal line, or "effective top tube length" (figure 1, p. 9-3), is measured from the center of the head tube to the center of the seat tube, and more accurately reflects the reach of the frame than the actual length of a sloping top tube. Identifying the size of a frame with compact geometry by seat tube length is as much an historical anachronism as anything else, since it has little bearing on the reach of the bike.

Many manufacturers now provide recommendations as to the range of rider heights a given size has been designed for. This can help simplify selecting the proper frame size, but does assume a rider of average proportions. For those riders with a ratio of upper body height to lower body height that falls outside of average values, additional considerations will need to be made.

Effective top tube length, in conjunction with the head tube length and the rise and length of the stem, ultimately determines the reach of the frame. Choosing a frame size that gives proper reach will not only ensure that the bicycle is comfortable, but that the weight distribution between the front and the rear of the bike is conducive to predictable handling. Most bike fitters strive for a weight balance of roughly 45% on the front wheel versus 55% on the rear wheel. Too much weight on the back wheel can adversely affect steering, resulting in a bike with "light" or sluggish handling.

Frame Geometry

In addition to the lengths of the tubes, geometry charts will often identify two important angles: The seat tube angle, and the head tube angle. The seat tube angle is the angle created between a line drawn through the center of the axles and the centerline of the seat tube. The closer this angle approaches 90 degrees, the steeper the seat angle. The more acute the angle, the more relaxed or slack the seat angle. Seat tube angle can affect not only the fit of the bike, but also the ride quality. A steeper seat tube angle results in a smaller rear triangle. Smaller triangles are not only stiffer, but provide more efficient power transfer. This efficiency, however, comes at the expense of vertical compliance. The steeper the seat tube angle, the more directly road shock is transferred to the rider. Steeper seat tube angles, commonly in the 73-75 degree range, are found on race-oriented bicycles. Touring bikes, commuter bikes, and other bikes designed for more casual riding use more relaxed seat tube angles, typically in the 72-73 degree range.

Relaxing the seat tube angle requires changing other aspects of the frame geometry. As the angle relaxes, the seat tube naturally gets closer to the tire. In order to prevent the tire from contacting the seat tube, the chainstays must be lengthened. This creates a larger rear triangle, which is more compliant, but can also lengthen the wheelbase. This, in turn, affects the handling characteristics of the bike. All things being equal, a bicycle with a longer wheelbase will exhibit more sluggish handling than one with a shorter wheelbase.

Seat tube angle also affects other aspects of fit. Larger riders, or those riders with longer femurs, require more relaxed seat angles to ensure that the knee may be positioned in the best location relative to the pedal spindle. Smaller riders, conversely, may require a steeper angle for the same reason.

The head tube angle of the frame, in concert with the fork offset, has the most impact on the handling characteristics of the bicycle. The head tube angle is the angle formed by the axle line and the centerline of the head tube. As with seat tube angle, steeper angles are associated with more race-oriented bicycles, while more relaxed angles are seen on touring bikes and commuter bikes. Fork offset, or rake, is the distance between the steering axis and the front axle. The head tube angle and the fork offset create what is called "trail" (figure 2, p. 9-6) To determine trail, extend the centerline of the head tube to the point at which it hits the ground. Now draw a vertical line from the center of the axle to where it intersects the ground. What you will see is the point where the line drawn down from the axle intersects the ground trails, or falls behind, the point where the steering axis line intersects the ground. More trail causes more stability at higher speeds, but results in a bike that requires more input from the rider in order to change direction. Conversely, less trail causes more stability at lower speeds, but results in a bicycle that requires small inputs to change direction at higher speeds. Bicycles designed to be highly maneuverable, such as criterium racing bikes, tend to have lower trail numbers than touring or commuter bikes, which favor stability over nimble handling.

Worth noting is that more offset will reduce trail, effectively quickening the steering, while less offset increases trail, resulting in slower steering. This may seem counter-intuitive, since we often associate radically curved fork blades with cruisers and more casual bicycles. Since fork offset has a direct correlation to trail, it is important to match the offset when replacing a fork. Otherwise, the handling may be adversely affected.

Stack and Reach

Another method of describing frame size that has gained popularity among triathlon, time trial, and downhill racing bikes is Stack and Reach. Initially championed by Dan Empfield of Quintana Roo, Stack and Reach distills frame size into two values: how

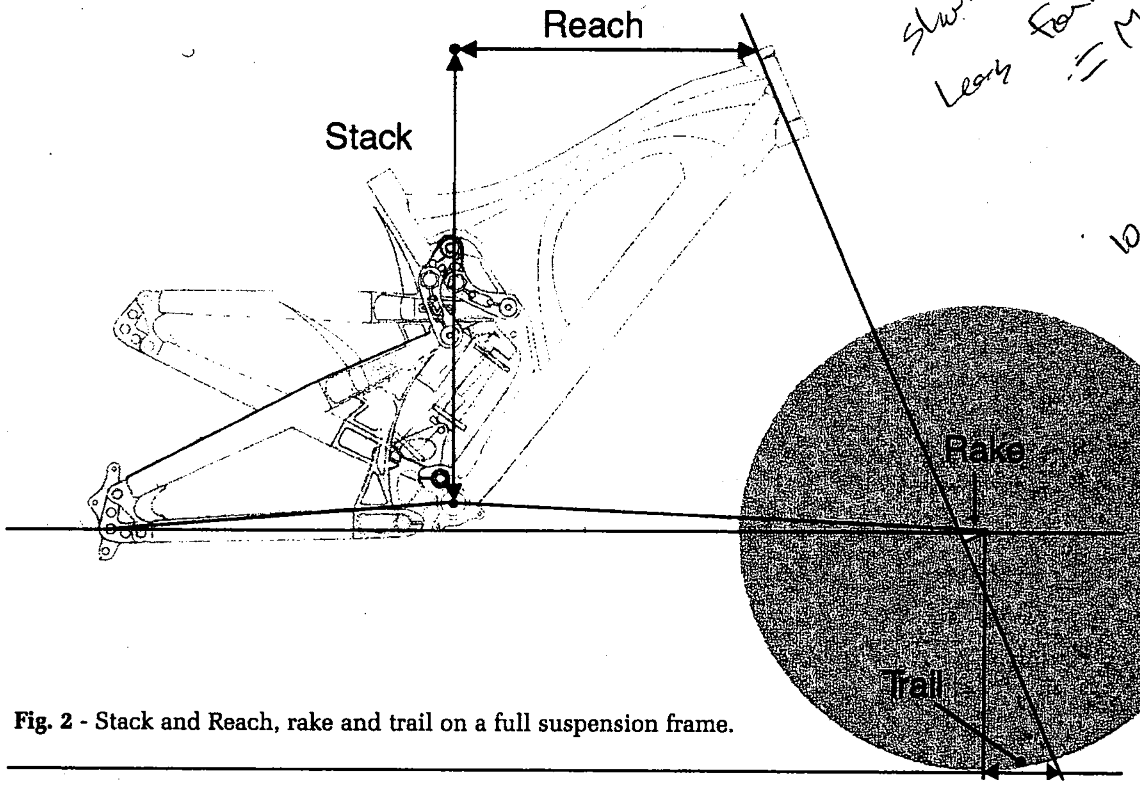


Fig. 2 - Stack and Reach, rake and trail on a full suspension frame.

Shallow HT angle
Long Fork offset rake
= More Trail

10mm Fork = .5°

high the top of the head tube sits above the bottom bracket center (Stack) and how far the top of the head tube sits in front of the bottom bracket center (Reach). Proponents of Stack and Reach argue that these values are much more meaningful than seat tube length and top tube length, and allow quick comparison between frames from different manufacturers. Many manufacturers have begun to include stack and reach measurements alongside more traditional sizing information.

Women's Specific Frames

Manufacturers often design frames around a hypothetical rider of average proportions. For those individuals who fall outside these average values, finding a production frame that fits properly can be challenging. Using anthropometric data gleaned mainly from women of western descent, manufacturers determined that women on average tend to have longer legs and a shorter torso when compared to males of the same height. To accommodate this perceived difference, manufacturers began producing women specific frames with shorter top tubes. While this approach certainly has merit, it is worth noting that many women do not share these traits, and would not necessarily benefit from a shorter top tube. Similarly, there are many men who have proportionately shorter torsos and for whom a "women's specific" frame would be more appropriate.

Determining Correct Frame Size

When most bicycles had horizontal top tubes, the most common method of determining correct frame size entailed assessing the stand-over clearance. The rider would stand over the bicycle with their feet flat and the floor and lift it off the ground with the tires level. The distance between the wheels and the floor indicated how much stand over clearance the rider had between the pelvic arch and the top tube. Road bikes had a suggested clearance of 1" to 4", while mountain bikes required clearance of 3" to 6". While stand-over clearance is still an important consideration, the prevalence of compact geometry on both road and mountain bikes makes the correlation between stand-over clearance and proper reach less direct. With T-shirt sizing, it is entirely possible for a given rider to fit comfortably on more than one size frame. In such cases, intended use may guide the rider to choose one size over another. A racer, for example, may choose the smaller frame to reduce weight and maximize efficiency. A more casual rider may choose the larger frame to gain some degree of compliance. Ultimately, assessing the position of the rider when seated on the bicycle, in particular the relationship of the torso to the upper arms, is the best indicator of proper frame size. This should be done with the saddle properly adjusted.

Special Considerations

There are cases in which a rider's specialized needs may go beyond the expertise of the bike fitter, and should be referred to a sports medicine professional. These include previous injuries that limit mobility, or dramatic discrepancies in leg length. Assessing leg length discrepancy can be done in several ways. Some fitters will have the rider hang from a chin-up bar and measure deviation, while others will have the rider sit with their back against the wall and their legs out in front of them. While minor leg length discrepancies are common, a difference of more than about 10mm may require consultation with a sports medicine professional.

BIKE FIT OVERVIEW

Once the correct frame size has been determined, optimum position can be achieved. It is important to note that there is no one "perfect" fit appropriate for every rider. Many factors, including riding style, flexibility, fitness, and intended use of the bike, will determine the most appropriate position. Most racers, for example, adopt a more aggressive position to maximize efficiency, power output and aerodynamics. This may result in a bike with considerable drop between the saddle and the handlebars. A touring or commuter bike, in contrast, would favor a more upright position to improve comfort and visibility. The primary goal in all bike fits is to establish a position that prevents injury. Comfort, efficiency, power and aerodynamics may then be prioritized accordingly.

Points of Contact

In simplest terms, bike fit involves fine-tuning the three points of contact until the desired position is achieved. These points of contact are the pedals, the saddle, and the handlebars. Ideally, fit should be performed with the rider and bicycle on a stationary trainer. The rider should be properly warmed up, and wearing the clothes and shoes they will be using while on the bike.

Pedal/Foot Interface

The interface of the pedal and the foot is crucial for proper bike fit. The varities of pedal systems are discussed beginning on p. 9-10. Clipless pedal systems, whereby the shoe is physically attached to the pedal via a cleat mechanism, are used not only by racers, but increasingly by recreational cyclists. The clipless pedal interface recruits all of the major muscle groups in the legs, allowing the rider to transmit power throughout the entire pedal stroke as opposed to simply pushing down. Proper cleat alignment, however, is crucial with clipless systems. Cleat position should address 4 variables:

1. Fore/aft position (front to back)
2. Rotational angle
3. Cant (varus tilt / valgus tilt)
4. Lateral position (side to side)

Fore/aft

Most fit systems advocate a fore/aft cleat position that places the center of the pedal spindle at the center of the first metatarsophalangeal joint (the ball of the big toe). Larger riders may move the cleat slightly behind the ball of the big toe to reduce the effective length of the lever arm. Moving the cleat too far back, however, can limit the rider's ability to sprint or climb out of the saddle. Conversely, moving the cleat forward of the ball of the big toe forces the calf muscles to work harder to stabilize the foot, and can contribute to pain in the Achilles tendon.

Rotational Angle

Establishing proper rotational angle is one of the most important aspects of cleat position. Incorrect angle can place undue stress on the knee and hip joints, contributing to chronic pain and severe injury. Rarely do individuals' feet face directly forward. Some naturally walk with toes pointed in, while others walk with toes pointed out. The cleats should be positioned such that the rider's natural biomechanical orientation is maintained on the bike. Many clipless pedal systems incorporate what is called "float." Float refers to the amount of free rotation allowed before the foot disengages from the pedal. Some systems have fixed float, while others offer adjustable float, via either an adjustment on the retention system or by selecting different cleats. In the case of systems with float, the neutral position, or middle of the float range should follow the rider's natural biomechanical plane.

Cant

Cant is the angle of the forefoot when viewed from the front. The forefoot cant is described as exhibiting either varus tilt (big toe elevated), or valgus tilt (little toe elevated). Tilt causes the knee to deviate laterally throughout the pedal stroke and the toe to move outwards, contributing to power loss and potentially stressing of the knee joint. Varus and valgus tilt can be corrected through the application of wedge-shaped shims. These shims may be installed between the cleat and the shoe, or inside the shoe like conventional orthotics. Establishing correct cant requires more experience on the part of the fitter, as well as access to a selection of shims or in-shoe wedges.

Lateral Position

The lateral position of the cleat should be adjusted such that the knee tracks in a vertical plane throughout the pedal stroke, ideally in alignment with the second toe. Cleats positioned too far to the outside of the foot may cause the knee to deviate outward, while cleats positioned too far inboard can bring the knee in towards the top tube. If the amount of lateral adjustment in the cleats is insufficient to properly align the knee with the second toe, additional pedal washers or special replacement spindles are often used by bike fitters.

PEDALS

There are dozens of brands, models, and styles of pedals on the market. Pedals utilize many different bearing designs, too, including needle bearings, cartridge bearings, bushings, and cup-and-cone bearing systems. Some pedals utilize more than one type of bearing. The current diversity of designs requires the mechanic to consult the manufacturer's service instructions carefully.

Despite this tremendous variety of designs, pedals can be classified into three main categories: cage-style, clipless and platform. In the case of cage-style and clipless pedals, the rider's shoe can be secured to the pedal body. Platform pedals allow the rider's foot to rest on top of the pedal body without being secured to it.

It is important to note here that pedal nomenclature has been highly inconsistent over the years and this can lead to confusion. For example, some older pedal designs were called "platform" but nonetheless used toe clips to secure the rider's shoes. Also, older designations like "rat trap," or "quill," described a certain variation of cage design.

Cage-style Pedals

Cage-style pedals are designed with a metal or plastic cage that is attached to the pedal spindle (see figures 7 and 8). The rider's foot rests on top of the cage, which is usually serrated to give the shoe extra grip on the pedal. This design has been in use since the mid-19th century, but with the proliferation of other pedal designs on the market since the 1980's, the cage design is seen less frequently. Historically, most cage designs used cup-and-cone bearing systems which, except for the cheapest pedals, were serviceable.

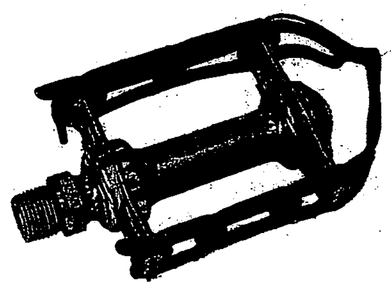


Fig. 3 - A cage style pedal known as a "quill" pedal.

Early in the development of the bicycle, riders discovered that they could transfer power more efficiently to the drive train if their feet were secured to the pedals. This allowed for pulling up on one pedal while pushing down on the opposing pedal. The method devised for securing the rider's feet was to mount a toe clip and strap to the pedal, a system still in use over 150 years later. The toe clip is typically a metal or plastic cage that mounts to the front of a cage-style pedal, cradling the foot. A strap loops through the cage of the pedal and through a slot on the toe clip, securing the rider's shoe. Until they widely adopted clipless pedals (discussed below) in the 1980's, road racers would supplement toe clips and

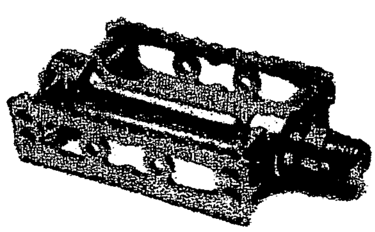


Fig. 4 - A cage style pedal

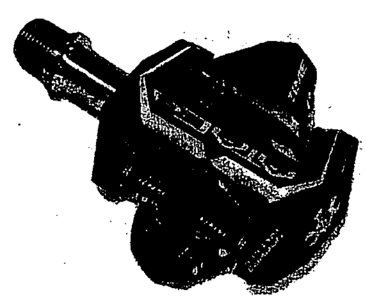
straps by mounting a metal or plastic cleat to the bottom of their shoes. The cleat had a horizontal slot cut into it that engaged the rear of the pedal cage, further securing the shoe to the pedal. However, these cleats prohibited any rotational float, and required extreme care in installation to avoid injury to the rider's knees. This type of cleat is rarely seen anymore, and cage-style pedals with toe clips are typically used on urban, commuter and touring bikes, because they allow the rider to gain some pedaling efficiency without having to wear cycling shoes.

Clipless Pedals

This type of system is called clipless because it retains the shoe without using a toe clip. While "clipless" is not the most accurate name - because of course the rider is still "clipping" into the pedal – it has gained wide usage in the industry. This design works on much the same principle as a ski binding. A cleat mounted to the bottom of the shoe attaches to a spring-loaded binding section of the pedal (although in some instances the spring is housed inside the cleat, rather than in the pedal). Clipless pedal designs existed as early as the 1890's, but the first modern clipless design was introduced by Cinelli in the early 1970's. It was not until a decade later that the French ski binding manufacturer Look produced the first clipless pedal to gain wide market acceptance. Other designs soon followed. An important feature of contemporary clipless pedals is that, unlike the clip-and-strap system, most designs permit the rider's shoes some rotational float. This allows the rider's knees to find a comfortable plane, thus avoiding injury.

There are two categories of clipless designs: recessed cleat and non-recessed cleat. The bike industry often uses a shorthand that refers to recessed cleat pedals as "mountain," and non-recessed as "road," although the distinction does not always hold true in actual usage.

Recessed (mountain)-cleat – This design recesses the cleat in the sole of the shoe, or, in the case of a mountain biking shoe, below the lugs of the sole. This allows the rider to walk easily. These are commonly used for any discipline where the rider may also have to run or walk: mountain biking,cyclocross, touring, or commuting, for example. The cleat is smaller than non-recessed cleats, and typically made of metal. Many of these pedal systems are double or quad-sided to allow for quick engagement.



Fig, 5 - An example of a pedal designed for a recessed cleat

The qualities that make this a good design for mountain biking, however, have some drawbacks in road racing applications. The recessed cleat design requires a higher pedal profile, reducing cornering clearance. The higher pedal profile also increases the distance between the pedal spindle and the rider's foot, which can slightly reduce pedaling efficiency and power transfer. Also, the smaller cleat localizes the pedal pressure on the sole of the foot, possibly causing "hot foot" on longer rides.

Non-recessed (road) - cleat - The cleats used with this pedal design mount to the outside of the smooth outer sole typical of a road shoe. The cleat is generally two to three times the size of the recessed style, and is usually made of plastic. This larger cleat distributes the pedal pressure over a greater area of the shoe, thus minimizing "hot foot." Most of these pedal systems reduce the distance between the spindle center and foot, increasing efficiency of the pedal stroke. Generally, these pedals are single-sided, which improves cornering clearance. However, the exposed cleats and smooth soles are not conducive to walking, so these systems are less desirable for disciplines like mountain biking or cyclocross.

Fig. 6 - A clipless pedal designed for a non-recessed cleat.

There are exceptions to the general principles of these two designs. For example,there are single-sided road pedals that are designed for the recessed style of cleat. Some pedal designs also incorporate a clipless retention system on one side and a "platform" on the other side.

On most clipless models, the binding system's spring tension is adjustable, allowing the rider to customize the amount of force it takes to release the shoe from the pedal. The cleats for the various models are designed for specific pedals and are not interchangeable among manufacturers. There is, however, a great deal of compatibility among various models of shoes, provided the cleat's bolt pattern matches that of the shoe. For a discussion of shoe/cleat compatibility, see Sutherland's Handbook, 7th Ed., chapter 2.

Platform Pedals

Platform pedals situate the foot on top of the pedal without being secured in any way, and are manufactured in a wide variety of shapes, sizes and materials. These include everything from the large, square pedals with replaceable pins used on downhill and BMX bikes, to the inexpensive plastic pedals found on children's bikes. The benefits to platform pedals are that they allow the rider a great deal of flexibility when it comes to shoes and foot placement, permit the rider to disengage from the pedal very quickly, and they provide a wide, stable platform for the foot. These advantages come with some penalty in pedaling efficiency, because the rider's foot is not secured to the pedal.

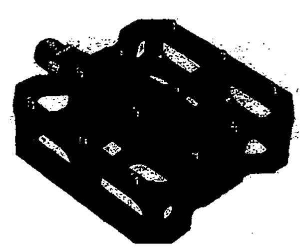


Fig. 7 - Two platform pedal designs. Top: A downhill/BMX style. Bottom: inexpensive "rubber block" style.

Evaluating Crank Length

Crank lengths are measured from the center of the bottom bracket spindle to the center of the pedal spindle in millimeters. Higher-quality cranks are typically available in 2.5mm increments; from 160mm to 180mm. Less-expensive cranks may only be available in 5mm increments. Manufacturers will often determine the appropriate crank length for a given frame size based upon a hypothetical average rider of a given height range. Some studies have suggested a correlation between femur length and appropriate crank length, while others suggest 20% of total leg length to be optimal. The bulk of studies published on the effect of crank length on performance, however, suggest that the difference in efficiency observed between commonly available crank lengths is minimal. Changing crank length can be an expensive proposition, and does not appear to confer substantial benefit except at the extremes of the range, such as 120mm or 220mm. Cranks in these lengths are not widely available, and their use has been limited to controlled biomechanical studies.

The intended use of the bike may also dictate crank length. Longer cranks give the rider increased leverage and mechanical advantage. This may be desirable for applications such as single-speed mountain biking or low-cadence climbing. Longer cranks, however, have the disadvantage of limiting the ability of the rider to spin the cranks rapidly. The foot must make a larger circle, and the range of motion of the knee and hip joint is greater with longer cranks. Shorter cranks, in contrast, are much more conducive to high-cadence pedaling. Track racers, who need explosive acceleration and higher RPMs, may choose shorter cranks for this reason. Shorter cranks also improve pedal clearance, a benefit when riding a fixed gear or downhill racing bike.

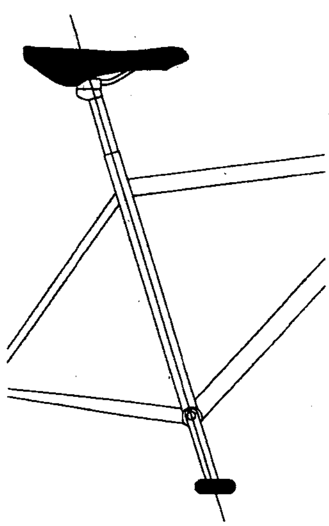


Fig. 8 - Measuring saddle height

Adjusting Saddle Height

Saddle height is one of the most crucial adjustments in the bike fitting process. Improper saddle height not only degrades performance, but can contribute to chronic knee pain and injury. Some studies suggest that for a given rider there may be a range of appropriate saddle heights. The higher the saddle position within that range, the more power is produced.

Several approaches are used by fitters to determine correct saddle height. Some involve measuring the rider's inseam and applying the resulting value to a formula, while others rely upon observing the rider while seated on the bicycle. The four most common methods are as follows:

1. Hamley and Thomas Method: Measure the rider's inseam in millimeters and multiply the value by 1.09. The inseam should be measured with the rider in socks or bare feet, and taken from the floor to the base of the pelvic arch. Multiplying the inseam by 1.09 provides the height of the top of the saddle measured from the crank / pedal interface, along the seat tube, with the crank in line with the seat tube.

2. Lemond Method: Named after famed American cyclist Greg Lemond, this method also uses the inseam to determine saddle height. After obtaining the rider's inseam in millimeters, multiply the value by 0.884. This is the saddle height measured along the seat tube from the center of the bottom bracket to the top of the saddle. This method does not take crank length into account, and is less commonly used than the Hamley/Thomas method.

3. Heel Method: The heel method entails having the rider sit on the bicycle while wearing their cycling shoes. Adjust the saddle height such that the heel just grazes the pedal with the leg straight and the cranks at the bottom of the pedal stroke. This method does not take variations in femur, tibia, and foot length into account. Some researchers have suggested that the heel method may not be appropriate for most riders, and often results in a saddle height that is too low.

4. Holmes Method: Currently one of the most widely used and accepted methods, the Holmes method involves measuring the angle of the knee at the bottom of the pedal stroke and adjusting saddle height until the optimal angle is achieved. To measure the knee angle, the fitter uses a device called a goniometer, which is readily available from medical supply sources. Studies have shown that the best angle for optimizing performance and efficiency and for preventing injury is 25 to 30 degrees. For the rider who wishes to optimize anaerobic power and aerobic efficiency, an angle closer to 25 degrees appears to be ideal. This method has gained widespread acceptance in part because it eliminates many variables, such as foot length, shoe sole thickness, and pedal stack height.

Saddle Fore/Aft Position

25-35° for pedal stroke fully extended

Once the saddle height has been determined you can now find the correct fore/aft position. This position is one which establishes the most efficient relationship between the forward-most knee and the pedal. The most widely accepted approach is often referred to as KOPS, or "Knee Over Pedal Spindle." This is the saddle position that places the tibial tuberosity, or bony protrusion below the kneecap, directly in line with the pedal spindle when the cranks are at 3 and 9 o'clock. Though no quantitative study has been produced that proves its validity, KOPS nonetheless seems to work for the vast majority of riders.

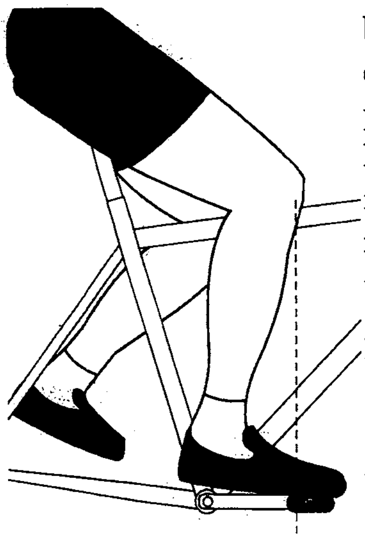


Fig. 9 Knee-over-pedal spindle (KOPS)

To make this adjustment, the rider should be seated on the bicycle, preferable on a stationary trainer. With their feet on the pedals and the cranks parallel to the ground, drop a plumb line from the tibial tuberosity of the forward-most knee. For most riders, the plumb line should intersect or fall slightly behind the pedal spindle. For long-distance road racers and cross-country mountain bikers this position may be adjusted further back up to 1 to 2cm.

It should be noted that there is a finite, usable range of adjustment for most saddles. Manufacturers will often indicate the safe clamping zone on the seat rails via a series of vertical hash marks. Clamping the saddle outside of this zone could exceed the strength of the rails, leading to failure. If proper fore/aft position cannot be achieved by clamping within this safe range, it is best to use a seatpost with a setback seat clamp. Seatposts with a range of setback values are readily available from most manufacturers.

Saddle Tilt

Saddle tilt is somewhat a matter of personal preference, and may be dictated by either riding style or the rider's anatomy. That being said, most saddles are designed to be positioned close to level. To determine saddle tilt, place a straight edge or carpenter's level across the saddle from tip to tail. Use a horizontal reference point or the level to assess the angle. Minor variations of a few degrees either up or down are considered acceptable. Extreme tilt in either direction will significantly affect rider comfort, and may be indicative of other fit issues. A saddle tilted too far upward will place undue pressure on soft tissues. One pointed too far downward will place more of the rider's weight on their hands and wrists, and may result in the rider feeling as if they are constantly sliding forward off the saddle.

Hands: The third point of contact

Once the pedal/foot interface and the saddle position have been established, the position of the rider's hands can be assessed. Adjustments can be made to stem length and angle (which determines the position of the handlebar), handlebar width and design, and the position of the control levers. Handlebar position is primarily a function of the intended use of the bike, and has the most direct effect on aerodynamic efficiency.

Stem Selection

At typical riding speeds, aerodynamic drag is the most dominant force acting on the bicycle and rider. 65 percent of this drag derives from the cyclist's body. Reducing the aerodynamic profile of the rider by adopting a longer, lower position can dramatically improve performance, but potentially at the expense of comfort and breathing efficiency. Regardless of the position or intended use of the bike, most fitters will attempt to maintain an angle between the torso and the upper arm of about 90 degrees, assuming a slight bend of 15 degrees between the upper and lower arms. A goniometer can be used to measure these angles, and stem length or angle adjusted accordingly. The old method of adjusting the bar position until the handlebar obscures the rider's view of the front hub has little to recommend it, and is no longer employed.

The reach of a stem is the result of two measurements: The extension of the stem, measured along the stem from the center of the handlebar clamp to the center of the steerer, and the rise of the stem. Rise is the degree to which the stem deviates from being perfectly perpendicular to the steerer. Two stems with the same extension may have entirely different reach measurements, depending upon the degree of rise. For example, a 100mm stem with zero degree rise would have 100mm of reach. A 100mm stem with 10 degrees of rise would have an effective reach of 80mm. For riders wishing to achieve a more aggressive riding position, threadless stems with rise may be flipped over to provide a stem with a corresponding degree of drop.

Dramatic changes in stem reach, either too short or too long, can have an adverse effect on the handling of the bike. Too short of a reach can bias the rider's weight towards the rear wheel, resulting in light or unresponsive steering. Too long of a reach can put too much weight on the front wheel, and can contribute to fatigue in the neck, shoulders, arms, and lower back. A stem of neutral length is, in most cases, ideal. Some disciplines, such as downhill racing, favor extremely short stems. A short stem places the bars closer to the steering axis, resulting in improved maneuverability at high speeds in technical terrain.

Quill stems provide some degree of height adjustment, allowing the rider to experiment with different bar positions relatively easily. With threadless stems, adjustment may be limited by the length of the steerer. When cutting a steerer to length on a threadless system it is advisable to cut 10 to 20mm longer than required and to place a spacer above the stem. This allows the rider to swap the spacer to a position below the stem, effectively raising the bars. Forks with carbon steerers often have strict limits on the amount of spacers allowable between the top of the headset and the bottom of the stem. Consult the manufacturer for specific recommendations.

Handlebar Width

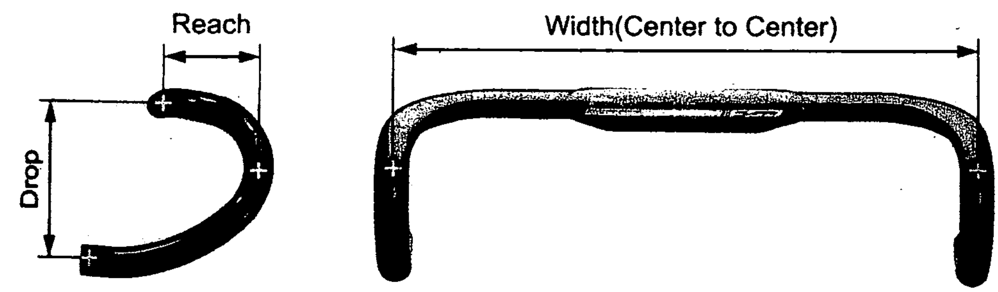


Illustration courtesy of FSA

Fig. 10 - Dimensions of a drop handlebar

The width of the handlebars affects the overall fit of the bicycle by widening or narrowing the base of the triangle created by the rider's arm. Handlebars fall into two main categories: Road bike handlebars, often referred to as 'drop bars', and the flat bars commonly seen on mountain bikes and city bikes.

Road bike handlebars are described in terms of their width, their reach, and their drop. How width is measured varies from manufacturer to manufacturer. Some measure from the center of one drop to the center of the opposite drop, while others may measure outside to outside. When ordering a replacement bar it is important to understand the method used by a given manufacturer so as not to change the customer's fit unknowingly. Widths are stated in either centimeters or millimeters, and are commonly available in 2cm increments from 38cm to 46cm. The most common method of determining proper width is to measure the width of the rider's shoulders and choose the size that most closely matches. Personal preference does play in to bar width. Those riders wishing to achieve more aerodynamic efficiency may choose a narrower bar, while those wishing to allow for easier breathing may choose a wider bar. A wider bar may also provide additional leverage to help with climbing out of the saddle.

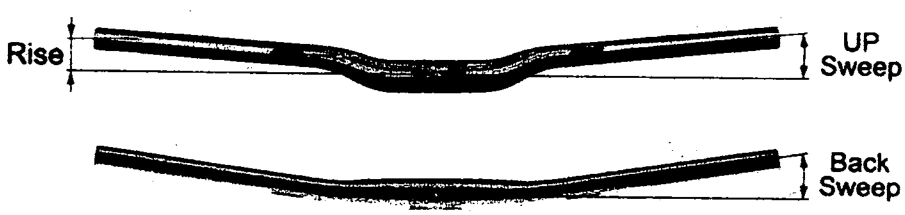


Illustration courtesy of FSA

Fig. 11 - Upright handlebars. Top: a riser handlebar viewed from the front.
Bottom: the same bar viewed from above, showing back sweep.

The appropriate width for mountain bike, or flat bars, is not so much dictated by the rider's physique, but more by discipline, terrain, and personal preference. In the early days of mountain biking narrower bars were favored, but bars have gotten wider and wider over the years. Currently, downhill racing handlebars are available in widths that approach those seen on motocross motorcycles. Flat bar width is expressed in inches or in millimeters, with widths of 20" to 28" being most common. Flat bars may often be cut shorter to suit a particular rider. There are limits, however, as to how much bars made of carbon fiber may be shortened. The portion of the bar where the controls are clamped must be reinforced, and removing this reinforced area can potentially lead to a failure. Always abide by the manufacturer's recommendations when altering the width of any handlebar.

Control Lever Position

Control levers should be positioned such that there is minimal bend between the lower arm and the wrist when the rider reaches for the brake lever. For bicycles with flat bars, this often means positioning the brake levers at a 45 degree angle. For drop bars, the shape of the bar, the shape of a particular manufacturer's control lever hoods, and the transition between the two may influence the final position of the levers. Riders who spend more time in the drops may prefer a position that allows better access to the levers while in the drops, while those who favor the hoods may bias the controls slightly upward. Some manufacturers of drop handlebars require a specific relationship between the lever and the drop in order to allow effective braking from all possible hand positions, and may indicate an acceptable range of adjustment.

After the Bike Fit

The human body is extremely adaptable. Nonetheless, once a rider is adapted to a given riding position, any changes should be made gradually and incrementally. Dramatic changes to saddle position, for example, can cause serious discomfort and in some cases injury. If multiple aspects of fit need to be addressed it is best to make one change at a time, allowing the rider's body time to adapt to each change before another is made. Changes should be documented so that they can be reversed should issues arise. If a bicycle needs to be disassembled or components transferred to another frame, be sure to make note of saddle position, handlebar position, and the placement of control levers. Many riders even record such things as saddle height, relationship of saddle to handlebars, and other fit data for future reference.

Stem Design and Compatibility

The handlebar and stem combination affects both handling and bike fit. There are three main styles of handlebars - drop style (road bars), aero, and upright (mountain bike bars). This chapter will discuss some variations within these three main categories, but in general the choice of design is a matter of rider comfort, riding style and personal preference. However, there sizing standards and system compatibility that the mechanic must consider.

Since all stems attach to the steerer tube of the fork, the first issue of compatibility must be steerer tube size. The steerer tube passes through the head tube of the frame and is attached to the fork crown. A steerer tube's size is based on its outside diameter. For decades, the 1" diameter (or 25.4 millimeters) head tube was standard. This was the size for road bikes, and early mountain bikes used it as well. As mountain bikes became more popular, manufacturers grew increasingly aware that the 1" steerer tube was not large enough to withstand the more abusive demands of mountain biking. Some mountain bike steerer tubes were bending too easily. By 1990, two new sizes were developed to strengthen the fork and allow both for more aggressive riding and the use of lightweight materials - 1-1/8" (28.6 mm) and 1-1/4" (31.8 mm). Of the two, the 1-1/8" size has become the most popular standard for most mountain bikes and road bikes. A standard that is also gaining wider acceptance is the "one-point-five" standard. It uses a 1.5" (38.1mm) steerer tube size.

There are two stem types: those for designed for threaded steerer tubes, and those designed for threadless steerer tubes. The two designs are differentiated by the method used to attach the stem to the steerer tube.

Stem Sizing: Height, Reach, and Rise

When discussing stem dimensions, we have to be concerned with stem height, reach and rise. Stem height is a term used for threadless stems only and is defined as the length of the stem's steerer tube clamp. There will be more about stem height later in this chapter. Stem reach and stem rise are a little harder to calculate.

Stem reach is the true length of the horizontal extension of the stem; that is, the horizontal distance between the center of the steerer tube and the center of the stem's handlebar clamp. Reach can be confusing because it depends on the stem's angle of rise. For example, a very long stem that has a steep rise can actually have the same reach as a shorter stem with a shallow rise. This is best illustrated by consulting the stem reach and rise template on page 13-5 of Sutherland's Handbook, 7th Ed.

Rise is the vertical height of the stem off the horizontal. However, it is most often expressed by the degree of the angle formed by drawing an imaginary line from the center of the handlebar clamp to the true horizontal. Depending on the type of stem (threaded or threadless) calculating the amount of rise is different. The rise of a threadless stem is the angle from a perpendicular line to the steerer tube. This usually is a small angle and can sometimes be negative (+5, 0 and -5 are common threadless rise measurements). The other method, used more with threaded stems, is the total angle from the steerer to the stem extension. Neither of these methods takes into account the head tube angle. Again, this is illustrated by the stem reach and rise template on page 13-5 of Sutherland's Handbook, 7th Ed.

Threaded Fork Stems

Stems for threaded forks have a quill which is secured to the inside of a threaded steerer tube. The quill is held firmly in place by a long bolt attached to an expander wedge. When the bolt is tightened at the top of the stem, the wedge slides upward and outward against the interior walls of the steerer tube, securing the stem to the fork. Since there are several sizes of steerer tubes, there are also several sizes of quills. A compatible fit is one that fits snugly inside the steerer tube with no discernible side to side movement. It should still be easy to slide the stem in and out. Some common quill sizes are 22.2mm (1" steerer tube) and 25.4mm (1-1/8" steerer tube). Additional quill sizes can be referenced by consulting the Sutherland's Handbook for Bicycle Mechanics, 6th Ed., page 14-2.

Stems designed for threaded forks have a minimum insertion (or maximum height) line inscribed on the quill above the expander wedge (figure 12). When installed into a fork, the insertion line should never be visible above the lock nut of the headset. This is to ensure the stem is inserted deep enough for sufficient support, and to guarantee the expander wedge is not exerting pressure against the inside of the threaded area. This condition can easily crack the steerer tube in the thin-walled area of the threads when the expander bolt is fully tightened.

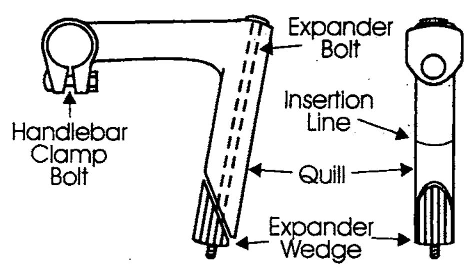


Fig. 12- Threaded fork stem

Threadless Fork Stems

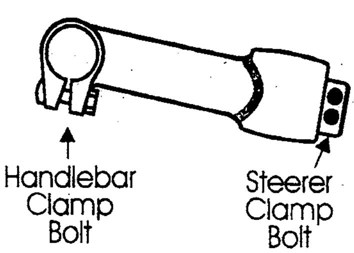


Fig. 13 - Threadless fork stem

Stems designed for threadless steerer tubes do not have quills because they clamp around the outside of the steerer tube. The steerer tube is therefore stronger because it does not have threads cut into it. Compatibility is a little simpler with this design. The inside diameter of the clamp must simply match the outside diameter of the steerer tube.

Handlebar Clamp Diameters

Stems' clamp diameters vary and in most cases are intended to hold only a corresponding size handlebar. The inside diameter of the stem's clamp therefore must match the outer diameter of the handlebar's midsection.

Mountain bike handlebars and stems are available in three diameters: 25.4 mm (often referred to as 1"), 31.8 mm and 35.0 mm. The 25.4mm is the more historic size, yet is still widely used. In the late 1990's the 31.8 mm clamp was introduced for increased strength. Because of the increased stiffness this dimension offered, road bike components also started to use the 31.8 mm clamp standard. Some manufacturers now offer handlebars and stems with a 35.0 mm clamp diameter, primarily for downhill racing.

Road bike bars have a more complicated array of handlebar clamp diameters. Fortunately, in current designs most handlebars come in one of three clamp diameters. The de facto road standard is 26.0 mm, but 31.8 mm (often referred to as the "oversized" standard) and the 25.4 mm ISO standard are also common. Never try to force an incompatible handlebar and stem combination. Trying to expand a stem to compensate for too large a handlebar will lead to cracking around the clamp. Too small a handlebar will make it impossible to tighten the clamp sufficiently. Additional information about handlebar and stem compatibility can be found in Sutherland's Handbook for Bicycle Mechanics, 7th Ed., pages 13-2 through 13-7.

HANDLEBAR DESIGN AND COMPATIBILITY

As mentioned earlier in this chapter, there are three types of handlebars used on bicycles - drop bars, aerodynamic bars, and upright bars.

Drop Handlebars

Drop bars are the traditional road bike style. They can be made out of a single piece of curved aluminum or steel tubing, with either a bulge in the center for the stem to clamp over, or a separate pressed-on sleeve, which acts as a shim. Drop bars are also being widely produced in carbon fiber. These bars come in different widths, intended to correspond to the width of the rider's shoulders . They also come in different drops (see figure 13). "Drop" is a center-to-center measurement from the top of the bars to the flat section at the bottom. Finally, bars come with different reaches. "Reach" is the distance between the centerline of the top of the bars to the centerline of the forward curve of the bar. Drop bars are 24 mm (+/-0.2mm) in diameter where components, such as brake levers, are clamped.

Generally, larger riders will use wider bars with greater drop and reach. Most of the women-specific bars on the market are narrower, with shallower drop and shorter reach. Most modern drop bars are also offered with some kind of anatomical shape to the drops in an effort to better fit the rider's hands, as well as grooves running along the front and/or rear of the (flat) upper section of the bar to recess the brake and/or derailleur housing.

Aero Handlebars

Aerodynamic handlebars may clamp directly into the stem or over the top of existing drop bars. These are intended for special applications such as time trials, triathlons and possibly touring. They are designed to place the rider in a fairly low position for aerodynamic efficiency. Most have some kind of support for the rider's forearms and extend outward over the front wheel of the bicycle. These bars are most often designed with drop bar clamping dimensions. When installing a "clamp-on" style of aero bar, it is important that the existing drop bar is compatible with the aero bar.

Upright Handlebars

Upright handlebars are either flat or curved slightly upward. Flat bars are rarely completely flat. Most have a slight bend to them, intended to be angled slightly rearward and upward to better fit the rider. Flat bars are still popular on some cross-country style mountain bikes. Some riders like to install bar-ends that clamp over the ends of the handlebar, adding a short forward extension that allows additional hand positions for the rider. When installing bar-ends it is important to ensure the bar is compatible for bar-ends. In the early 1990's handlebars with built-in bar-ends were popular on mountain bikes, but these have all but disappeared. Variations on this bar style are still frequently seen on the loaded touring bikes, known as trekking bikes, popular in the European market. Upright handlebars are 22.2 mm in diameter where components clamp.

Many handlebars have a pronounced upward curve to them, and are generally referred to as riser bars. These bars will typically have between 1" and 3 1/2" of rise. BMX handlebars usually have between 4" and 6" of rise and "chopper" bikes have bars with exaggerated rise.

Handlebar Coverings and Grips

In order for riders to secure a more positive grip to their handlebars and to provide more padding, handlebars are covered with tape, foam, or rubber grips. Tape is used on road bike drop and aero bars and can be made out of a variety of materials, including cloth, plastic or other synthetics, and cork. Cloth tape was popular prior to the 1980's and is still available. However, the market is now dominated by a wide range of synthetics, as well as cork-based tapes, which offer greater durability and better padding than cloth.

When wrapping drop handlebars, there are obviously two options for a starting place - the top or bottom. Many machine-wrapped bars begin at the top and are wrapped to the end, with the leftover tape being stuffed beneath the handlebar end plug. However, because of the direction of the tape's overlap when starting from the top, the rider's grip tends to unwrap the tape over a period of time. Most professional mechanics wrap in the opposite direction, from the end to the top. The direction of the tape's overlap allows the tape to stay snug against the bar, resisting the rider's hand pressure.

Upright handlebars generally use foam or rubber grips on their ends. These are available in a wide variety of shapes, colors, and materials. Mountain bike handlebar ends have a universal outside diameter of 22.2 millimeters and all mountain bike grips are designed to fit this size, so compatibility is generally not a problem. Some grips rely on locking collars, instead of a press fit, to secure to the handlebar. "Lock-on" grips install and remove easier, while being more secure to the handle bar than a traditional grip. When working with carbon fiber handlebars it is important to ensure handlebar compatibility when considering "lock-on" grips.

SADDLES

There are a number of factors to consider when choosing a saddle. Certainly weight, function, and looks play a role, but fit is number one. To determine fit, one of the first things to consider is the anatomical structure of the person choosing the saddle; most importantly, the location of the ischial bones of the pelvic girdle. These bones, often referred to as "sits" bones, will determine how wide a saddle needs to be. The sits bones should be centered at the rear of the saddle to provide the best support.

Most saddle manufacturers offer many different types of saddles both in a "men's" and "women's" style. Typically, the "men's" style is narrower at the rear and longer front-to-back, while the "women's" style is wider at the rear and shorter. These two different classifications are based on the general assumption that women are smaller in stature, but have a wider pelvic structure. Unfortunately, this creates a misleading distinction about "men's" vs. "women's" styles which could keep someone from buying the type of saddle that fits best. A man with a pelvis that's wider than normal may be most comfortable on a "women's" saddle, and many women find they're most comfortable on "men's" saddles.

Another important factor to consider is the condition of the rider. If a rider is new to cycling, or if it is early in the season, the muscle tissue surrounding the sits bones may not be developed enough to adequately support the rider. In this case, it would make sense to start out on a saddle with generous padding. As the muscle tissue becomes more toned, the rider can ride a firmer saddle more comfortably.

The best advice when looking for the right saddle is to "shop the shape." In other words, find the best shape of saddle that corresponds with the rider's anatomy and be prepared to make several switches before finding the right saddle. For a shop, this could mean that a customer makes many visits before finding the correct saddle. To meet this demand, a number of wholesale distributors and manufacturers sell saddle test kits to shops that allow them to make available a whole range of the manufacturer's saddles for customers to test ride.

One other note regarding saddles and bike fit: changing saddles usually alters the rider's position on the bike. For example, some saddles are taller than others; that is, the distance from the seat rails to the top of the saddle is greater. When fitting a rider with a taller saddle you may need to lower the seatpost a corresponding distance to maintain the rider's proper leg extension.

SEATPOSTS

A seatpost's main function is to mount the saddle to the frame, giving the rider a range of adjustability both up and down, and fore and aft. Seatposts can vary in design considerably from manufacturer to manufacturer. Clamp design, clamp offset, length, diameter, and material are the most common differences.

The most noticeable differences are seen in clamp design and offset. The clamp of the seatpost is designed to hold the rails of the saddle and provide a small amount of adjustability fore and aft. These clamps can come in a variety of designs: single bolt, double bolt, notched micro adjust, smooth convex and concave, and even suspension.

Offset can affect the rider's position on the bike. Seatposts which offset the seat clamp behind the center line of the post could move the rider's saddle rearward a centimeter or more from a post that has no clamp offset. If a new seatpost changes the saddle offset, corresponding changes may need to be made elsewhere on the bike in order to maintain the rider's position.

Manufacturers offer seatposts in a variety of diameters and lengths. The seatpost diameter (commonly referred to as its size) is dependent on the frame it is going on. Frame manufacturers will specify a seatpost size based on the material, and the construction method used. Seatpost manufacturers generally have tolerances built into their sizing. For instance, a 27.2mm seatpost may actually measure 27.1mm. Some manufacturers may have tolerances as high as 0.5mm. The length of a seatpost may also vary depending on use. Most commonly, seatpost lengths vary from about 200mm to about 400mm.

Sizing a seatpost is not always as simple as buying the size that the manufacturer recommends. The best way to size a seatpost is to have a stock of dummy seatposts that you can insert into the frame to check for proper fit. The seatpost fits when you can slide it up and down freely without twisting, and it doesn't have any slop from side to side. It is not a good idea to try to measure the inside diameter of a frame, because it is difficult to measure the inside diameter of the seat tube low enough to check the area where the most distortion occurred during manufacturing. A seatpost should fit so that when the binder bolt is tightened, it requires only 1/4 to 1/2 turn to secure it.

STUDENT HANDS-ON:

Handlebar Tape Installation

Step 1 - Select a road bike. Remove the handlebar tape.

Step 2 - Rewrap the handlebars with the existing tape, if reusable. If the tape is torn and cannot be reused, check with an instructor for new tape.

Step 3 - Begin at the end of the bar with half the width of the tape overhanging the end.

Step 4 - Have each wrap overlap the previous by one third, increasing to one half at the curve.

Step 5 - At the lever, leave space for one wrap underneath the lever and cross around the back in a figure-eight pattern, wrapping over the space left over, then coming over the top of the lever and continuing with wrapping the bars.

Step 6 - When the tape has reached the bulge/sleeve at the top of the bar, cut the tape at an angle so that the sharp edge will be facing the stem and that the angle matches the shape of space available. Secure with electrical tape by wrapping half on the tape and half on the bar.

Bicycle Overhaul

A bicycle overhaul is a very common service procedure in a shop. As with new bike assembly (discussed later in this chapter and in the chapter appendix), an overhaul is best performed with the aid of a checklist. The use of a checklist ensures thoroughness, quality control and helps limit exposure to liability. You will be given a separate checklist in class for the bike overhaul hands-on, and that checklist will be handed in at the end of the day. A version of the UBI class overhaul checklist is also included below for you to refer to or adapt to your future needs.

Bicycle Overhaul Check List

Disassemble Bike

- ❑ Clamp bike in repair stand by seat post only.
- ❑ Before disassembling bike, quickly assess the condition of the bike and its systems. Make notes of any issues.
- ❑ Shift front and rear derailleurs into neutral position. Cut derailleur cable ends, loosen derailleur cable anchor bolts, and remove derailleur cables and housings.
- ❑ If bicycle is equipped with caliper brakes, cut brake cable ends and remove cables and housings. If bicycle is equipped with linear pull brakes, loosen brake quick releases and remove brake cables from brake levers, cut brake cable ends and remove cables and housings.
- ❑ If necessary to access housing, unwrap bar tape from handlebars.
- ❑ Remove wheels from bicycle.
- ❑ If bicycle is equipped with a quill stem, loosen quill expander bolt and remove handlebars from bicycle. If bicycle is equipped with a threadless stem, remove stem faceplate and remove handlebars from bicycle.
- ❑ Remove chain from bicycle. If equipped with a master link, use master link to remove chain.
- ❑ Remove pedals from crank arms.
- ❑ Remove cranks. Be sure to check for crank bolt washers.
- ❑ Remove chainrings from crank arm.
- ❑ Loosen cable guide bolt and remove bottom bracket.
- ❑ Remove both front and rear derailleurs.

- ❑ If bicycle is equipped with caliper brakes, remove brake calipers from bicycle. If bicycle is equipped with linear pull brakes, remove brake arms from bicycle.
- ❑ Remove brake pads from brake calipers/brake arms. Pay attention to the orientation of washers, if any are present.
- ❑ If bicycle is equipped with a threaded headset, measure locknut lip clearance, loosen and remove locknut, any spacers or accessories, and threaded race. Set fork aside, keeping track of bearing orientation. If bicycle is equipped with a threadless headset, loosen top cap, measure stem/steerer gap, remove stem, any spacers or accessories, compression ring, and headset race. Set fork aside, keeping track of bearing orientation.
- ❑ Remove headset pressed races.
- ❑ Remove crown race from crown of fork.
- ❑ Remove cassette or freewheel from rear wheel using appropriate tool.
- ❑ Remove tires and tubes from both wheels.

Headset

- ❑ Clean pressed races of any excess grease.
- ❑ If the bicycle has a conventional threaded headset, reassemble according to the directions in the UBI manual (Chapter 7).
- ❑ If the bicycle has a threadless headset, reassemble according to the directions in the UBI manual (Chapter 7).
- ❑ Headset should be adjusted so bearings operate as smoothly as possible with out play.
- ❑ Reinstall quill stem to maximum height and handlebars (if threaded) or handlebars and stem faceplate (if threadless) and secure bolts. DO NOT TORQUE. Handlebar/stem bolts will be torqued at the end of the overhaul.

Wheels

- ❑ Adjust both front and rear hubs so bearings operate as smoothly as possible without play.
- ❑ True front and rear wheels in truing stand using a tightly fitting spoke wrench. Wheels should be laterally true, radially true and dished to within 1mm tolerance.
- ❑ Disassemble both front and rear hubs.
- ❑ Reassemble and adjust both front and rear hubs. Lightly grease full length of quick release skewers before installing into axles.

- ❑ Check wheels in dropouts for final hub adjustment. There should be play in the hubs with the quick release lever at 45 degrees, but no play in the hubs when quick releases are fully closed. Readjust hubs if necessary. When correct, remove wheels.
- ❑ If freewheel equipped: grease freewheel threads and reinstall freewheel. If cassette equipped: reinstall cassette, grease lockring threads, install and tighten to manufacturer's torque specification.
- ❑ Install tubes and tires, centering label over valve hole with label facing the right side, unless rotation direction on tire indicates otherwise.
- ❑ Inflate tires to 20 psi and check that the tire bead is properly seated, and then inflate to maximum pressure as printed on the tire's sidewall.

Bottom Bracket

- ❑ Install chainrings on crank arm in proper orientation. Torque chainring bolts according to manufacturer's specification. Replace any damaged bolts.
- ❑ Clean threads of bottom bracket shell.
- ❑ Apply grease to fixed cup threads.
- ❑ Tighten fixed cup to appropriate torque.
- ❑ Grease threads and reinstall adapter cup; torque to manufacturer's specification.
- ❑ Reinstall crank arms.
- ❑ Torque crank bolts to manufacturer's specifications. Be sure to reinstall crank bolt washers.
- ❑ If provided, install toe clips, straps and reflectors on pedals.
- ❑ Grease threads on pedals and install. Tighten to the manufacturer's torque specification .

Brakes

- ❑ Seat wheels properly in dropouts.
- ❑ Install wheels with quick releases properly tightened.
- ❑ Inspect all brake housing. Replace if necessary.
- ❑ Grease brake cables and install into housing.

- ❑ Set up brakes according to directions provided in the UBI manual (Chapter 6).
- ❑ Be sure to grease all cable anchor bolts.

Be sure to adhere to the following guidelines when setting up brake shoes:

- ❑ Shoe Height: Pad should contact rim so there is a 1mm gap between top of pad and top of rim or sidewall of tire.
- ❑ Shoe Angle: Pad should follow rim squarely from top to bottom
- ❑ Shoe Interface: Pad face should contact rim squarely and equally with surface of rim.
- ❑ Shoe Toe-in: If the bicycle is equipped with linear pull brakes, there should be a .5 – 1.5mm gap at the rear of the pad just as the front makes contact with the rim.

Final Brake Check and Failure Test:

- ❑ Stress cables and seat the housing system by squeezing the brake levers several times. This will ensure that all anchor bolts are tightened properly and there are no flaws in the system.
- ❑ When finished pre-stretching, lever travel should not exceed two thirds of its full travel to the handlebars.
- ❑ Brakes should be centered and both brakes should feel the same at the lever.

Derailleurs

- ❑ Make sure shift levers are in their neutral position.
- ❑ Grease front derailleur clamp bolt threads and reinstall.
- ❑ Check and adjust front derailleur cage height and angle. Bottom of outside cage should be 1-3 mm above highest point of large chainring. Cage angle should be parallel to large chainring.
- ❑ Torque front derailleur clamp bolt to manufacturer's recommendation.
- ❑ Grease hanger bolt threads and reinstall rear derailleur. Torque bolt to manufacturer's recommendation. Avoid trapping "B" tension screw against face of derailleur hanger.
- ❑ Grease derailleur cables and reinstall into housing.
- ❑ Reinstall chain.
- ❑ Adjust rear derailleur limits.

- [ ] Perform rear derailleur index adjustment.
- [ ] Once rear derailleur index adjustment is acceptable, adjust front derailleur limits and perform front derailleur index adjustment.

Final Derailleur Adjustment and Fine Tuning:

- [ ] Shift through all possible gear combinations and fine tune front and rear derailleur adjustments, if necessary.

Finish

- [ ] Align handlebar and stem with front hub or fork crown and torque stem or quill binder bolts and stem faceplate bolts to manufacturer's specifications.
- [ ] If necessary, wrap handlebars with bar tape.
- [ ] Trim and cap all cables.
- [ ] Perform a complete safety check on bicycle:
- [ ] Check brakes by firmly squeezing levers several times.
- [ ] Check tightness of stem, handlebars, control levers, seat post and saddle.
- [ ] Check tightness of front and rear quick release skewers and/or axle locknuts.

New Bicycle Assembly

Newly hired mechanics are often assigned bicycle assembly as their primary task. This isn't necessarily a good idea. Despite the importance of a safe, thorough, and efficient assembly, the job is often regarded as somehow beneath the skills of a master mechanic. Bike assembly tests many mechanical skills, and mistakes can be costly.

Shop philosophy on new bike assembly ranges from doing little besides pulling off the packing material and installing the wheels to an all-day endeavor that includes overhauling every bearing assembly and truing the wheels. In class we lean more towards the latter example, stressing a comprehensive assembly, but also keeping an eye on the clock. Speed is important in new bike assembly, but safety and quality are the top priorities. Many mechanics are under the assumption that faster is always better, that a quick assembly is the hallmark of an expert mechanic. But if a hastily assembled bike comes back to the shop a week later needing a number of adjustments, no time has been saved. The implications of a customer injury resulting from a hasty or sloppy bike build are even worse. It is up to the shop owner to decide exactly how much time is allotted for an assembly.

Consistency

The condition of new bikes on the floor of a shop is the most obvious indication of the shop's quality and commitment. The shop needs a system of assembly that is rigidly and consistently followed by all of its mechanics. If ten different bikes on the floor look like they were assembled by ten different people of varying mechanical aptitude, the customer's decision may be affected. Most likely, they'll decide to buy their bike elsewhere.

Safety

Nothing turns off a potential customer like crashing on a demo bike. It's all too easy in a busy shop to forget such operations as tightening stem bolts or brake cable anchor bolts. The safety of the rider needs to be kept in mind throughout the assembly process. A poorly assembled bike not only endangers the rider, but in our litigious society, it can also mean the end of an otherwise successful shop. Many businesses have been sued out of existence for far less than causing a customer to crash a bicycle. The mechanic should test ride every newly built bike before putting it on the sales floor. Test rides often reveal problems that weren't apparent when the bike was in the work stand, and are therefore an important step in any assembly process.

Effect on New Bicycle Sales

Bicycles should always be assembled so that they ride as well as they possibly can, given a reasonable amount of assembly time. If Shop A's $500 bike is assembled better than Shop B's $500 bike, a consumer doing comparison shopping will be more likely to buy their bike from Shop A. They'll notice that the bike rides smoother, shifts quieter, and the brakes work better. Whether they chalk up the difference to better assembly or simply a better bike is irrelevant. Either way, shop A makes the sale.

Consider the same scenario applied to two bikes at the same shop. Given an expertly assembled $300 bike and a shoddily assembled $400 bike, most people will prefer the ride of the $300 one. Why, they'll wonder, does a cheaper bike ride so much better? This phenomenon is difficult to explain to someone without discrediting either the shop's service department or the bike's manufacturer. An effective assembly will make the difference between bikes at two price points obvious, and hopefully will steer the customer to the higher quality one. Although it is a poor policy to push someone into buying something more expensive than they can use, there's no reason to take money out of your own pocket either.

Assembly Checklists

Most bicycle shops use some form of assembly checklist. The detail of the checklist varies widely among shops. Many checklists are brief, noting only major operations of the assembly. On the other hand, some shops prefer to use multi-page documents detailing each step, including torque specifications, etc. Of course, the length of the checklist isn't as important as how comprehensive the assembly itself is. A short checklist works perfectly well as long as the mechanic is experienced enough to remember how to perform each step properly.

Use of a well-written assembly checklist helps prevent a missed step in the assembly, which could have serious safety and liability implications. It's especially important to have a good checklist in a busy shop, where the mechanic is likely to be interrupted. In many cases, assemblies are performed during down time in a shop, and the assembly may need to be put aside to attend to another, more pressing task. Use of a checklist assures that the mechanic won't lose his or her place in the assembly during interruptions.

Occasionally, a bike manufacturer will provide its own checklist to be used in assembly of its bikes. Again, the purpose is to assure a safe and proper assembly, and to give a measure of protection against legal action. If the assembly list is to your liking, you may choose to use it exclusively. If not, you should use your own in addition to the manufacturer's. Although this sounds like a bother, it's much easier than spending time in court.

A suggested new bicycle assembly checklist is included in the Appendix at the back of this book.

ADDITIONAL READING ABOUT BIKE FIT

The purpose of this list is to provide some alternate sources to help you learn more about the material covered in class. There is no requirement to do any of this reading. Read as little, or as much as you would like.

Some Commercial Fit Systems:

Bike Comfort

http://www.bikecomfort.com/

Bike Fit Systems

http://www.bikefit.com/

Fit Kit Systems

http://www.bikefitkit.com

Retül

http://www.retul.com/

Serotta

http://www.serotta.com/fit/index.html

Wobble-Naught

http://www.wobblenaught.com/

Web Resources:

Keith Bontrager	"The Myth of KOPS: An Alternative Method of Bike Fit"
	http://www.sheldonbrown.com/kops.html
Bill Boston Cycles	"Bill Boston on Bicycle Design and Fit"
	www.billbostoncycles.com/bicycle_fit.htm
Sheldon Brown	"Revisionist Theory of Bicycle Sizing"
	www.sheldonbrown.com/frame-sizing.html
Jim Langley	"Bike Fit Problems and Solutions"
	http://www.jimlangley.net/crank/bikefitchart.html
Peter White	"How To Fit a Bicycle"
	http://www.peterwhitecycles.com/fitting.htm

Chapter 10

Writing Repairs, Shop Operation, and Customer Service

Objectives:

- Learn proper diagnostic techniques and repair tag writing
- Understand margins and profitability within the bike shop

Being the best mechanic in the bicycle industry is a lofty goal, but no matter how accomplished a mechanic may be, to be successful he or she must combine mechanical skill with good, solid business sense. Many shops are started by enthusiasts who love to ride, work on, live and breathe bicycles. This type of enthusiasm is great for supplying the energy necessary to start a business, but rarely is it enough to ensure long-term success.

Simply put, an independent bicycle dealer (IBD) is in business to make money. That doesn't mean that profit should be a dealer's sole motivation. It simply means if your store is not profitable, it will soon cease to exist. The need to be profitable might sound like a no-brainer, but quite often new shops quickly go out of business because the owners' and employees' romantic relationship with the bicycle hinders their ability to make sound business decisions.

Currently, there are around 4,200 bicycle dealers in the U.S. In an average year, approximately 1,000 new bicycle dealers open their doors for the first time, and another 1,000 go out of business. In fact, studies have shown that about 70% of all new retail businesses do not last the first three years. So a love of bicycles is simply not enough to be successful in the bicycle industry. You must also be able to temper that love with good business sense and a strong desire to develop and use all the other skills necessary for success - skills such as merchandising, accounting, inventory control, purchasing, advertising, customer service, and yes, also wrenching on bicycles.

So whether you own, intend to own, or are employed by a bicycle shop, the success of the business depends on you. This chapter will introduce you to some effective ways to promote the profitability of a retail independent bicycle dealer. It will also introduce you to some of the basic concepts and procedures necessary to make the shop's service department profitable. It is in no way intended as a comprehensive guide to running a business. If you plan to open a shop, UBI highly recommends that, in addition to the mechanics training you receive from this course, you pursue a sound education in retail business skills. There are excellent resources available to you at local community colleges and business trade schools, as well as from the bicycle industry trade organizations mentioned in this chapter.

TAKING IN REPAIRS

When a customer brings in a bicycle for repair, it is important the mechanic makes an accurate assessment of the repair, writes it up on the proper repair tag in a legible and comprehensive manner, and accurately determines the estimate. This should all be performed while the customer is in your presence. Mechanics should develop a routine to follow that allows them to go over the entire bicycle, component by component, diagnosing any problems along the way. Each problem encountered should be pointed out to the customer along with the repair options and costs, and then written down on the repair tag if the customer wishes the repair to be performed.

All labor costs should be based on a pre-established rate sheet (more on this later) and should be recorded along with the potential replacement parts costs. It is always a good idea to overestimate the repair. In fact, some shops that are very customer service-oriented do this as a matter of policy. When a customer receives their newly repaired bicycle and the price is under the amount they thought they would have to pay, they go home happy, knowing they were dealt with fairly by the shop.

If additional problems are found later during the repair, especially ones that are significantly more costly than the original estimate, a phone call to the customer is in order. Tell the customer the problem you found, what the options are, the additional cost that must be incurred, and let the customer make the decision on whether to have you perform the extra work. This is a far better approach than to have the customer discover a $20 repair has turned into a $50 repair by the time they picked up the bicycle. This could make the shop look unprofessional and perhaps even dishonest.

Of course, the best approach is to avoid poor estimates to begin with by properly diagnosing the bicycle as you are estimating the repair. The following guidelines are useful if you have never done an estimate before. Once you gain a little experience, you will undoubtedly develop your own style and routine.

Diagnosing and Writing Up the Repair

1. Start at the front of the bicycle and work your way rearward. Begin by squeezing the front brake levers and rocking the bicycle back and fork. Do you feel a loose headset? Do the brakes engage properly? Are the levers, handlebars, and stem tight? Do the brake calipers have excessive play? Are the brake pads, cables or housing worn? Do hydraulic brakes show signs of fluid contamination or leakage?

2. Place the bicycle in a repair stand, get out a blank repair tag and pen, and go over the bicycle, step by step, with the customer (see figure 1).

3. Start by checking the frame and fork for damage. Look for any signs the bicycle may have been involved in a crash. Visually inspect the alignment of the fork and rear triangle.

4. Continue by sighting down to the front wheel. First, make sure the quick release is tight, then spin the wheel to check trueness. Inspect the condition of the hub, rim, spokes and tires. Grab the tire and wiggle the wheel laterally. Are the hub bearings loose? Let go and let the valve stem roll to the bottom. Does it drop freely or is the hub too tight?

5. Move now to the rear wheel and perform the same actions on it. Squeeze the rear brake lever and check for loose or tight hub bearings, trueness, and the condition of the hub, spokes, rim, and tire. Check the rear cogs for wear or damage.

6. Spin both pedals, making sure they spin freely with no binding, and that they are true. A wobbly pedal denotes a bent pedal spindle.

7. Inspect the crank arms and chainrings for wear, damage, and loose or missing chainring bolts.

8. Grab the ends of both crank arm and wiggle them back and forth laterally as you check for a loose bottom bracket. Turn the cranks slowly to check for roughness. Lift the chain from chainring and let cranks spin freely. Are they too tight?

9. Turn the cranks and shift through the entire range of gears, both front and rear, making note of any derailleur adjustments or repairs that must be made. Then let go of the cranks and let them come to a stop. If they keep spinning, there is a problem with the freehub body or freewheel internals. Note: Caution should be taken when shifting into the big/big combination, in case the customer's chain is too short.

10. Finish the inspection by checking for worn, damaged, or loose peripheral components, such as the seat and seat post, racks, lights, water bottle cages, etc.

11. Add up the estimated labor costs and parts costs separately and record them all onto the repair tag, remembering it is always best to overestimate. Make sure you also get the customer's name, address, e-mail and phone number on the repair form. Some forms have an authorization line to be signed by the customer. Make sure the customer signs it.

12. Estimate how long it will take to perform the repair and record a pick-up date. It is also best to overestimate the pickup date, both to allow the shop enough time to perform the repair, and to please the customer with an early call if the bike is ready before it was promised.

Although the preceding steps seem time-consuming, the actual inspection should take no more than 2 or 3 minutes. Extra time spent now can save you valuable time later, and reduce the chance of underestimating a potentially costly repair.

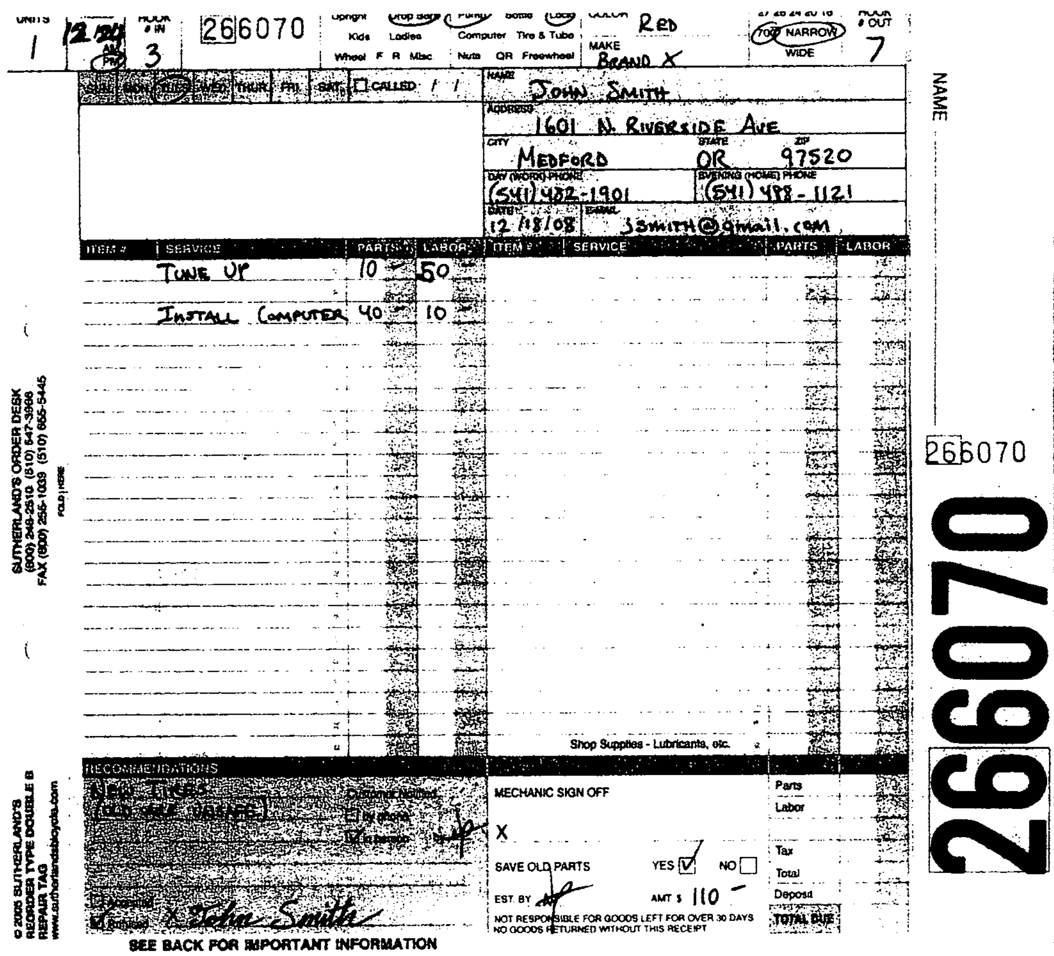


Fig. 1 - A properly completed shop repair tag

USING A FLAT RATE CHART

Service charges should not be based on opinions. Precise service charges should be established for common service routines and consistently utilized. Every store should develop its own flat rate service chart, listing a charge for everything from handlebar re-wrapping to complete overhauls. The benefits of using pre-established shop rates are many. Repair estimates will be determined more quickly and accurately, consistent estimates will be established no matter who writes up the repair, and undercharging for repairs will be avoided.

This last principle is perhaps the most important. Most shop employees have no idea what the shop's overhead is and therefore can easily charge too little for repairs if a flat rate is unavailable. Flat rate chart amounts are based on two values and the following simple formula:

Flat Rate = Hourly Service Charge x Repair Time

The hourly service charge is not the amount the mechanic is paid per hour, but rather the shop's pre-established amount based on its overhead expenses. Nationally, the average amount ranges from $25 to $60 or more per hour. For example, if the shop's hourly service charge is $60 per hour and the amount of time it takes to perform a standard tune-up is 1 hour, the amount the shop charges for that service would be $60. If a simple derailleur replacement is being performed and it takes the mechanic 15 minutes to complete the job, the amount would come to $15.00. 15 minutes is 1/4 of an hour so we could calculate the cost of the repair by multiplying the hourly rate of $60 by .25.

Routine repairs should have time values already calculated and established. These should be listed on the shop's flat rate chart. For example, it should take the average mechanic no more than 30 minutes to overhaul a headset, so the amount listed on the shop's flat rate chart should be $30. This amount should always be charged, even if the mechanic completes the job in only 20 minutes. This is the true value of a flat rate. An efficient mechanic can make the shop more profitable when the service is performed more rapidly. This also allows for more flexibility when a new or less proficient mechanic performs the work.

The following sample flat rate chart is provided to give you a starting point. The time values are based on industry-established standards and reflect the amount of time the average mechanic should take to perform the given procedure. The dollar amount charges are based on a shop service rate of $60 per hour. If your shop service rate is different than this, simply recalculate yours with the time values given. This chart is by no means complete. Feel free to customize and add to it to make it suit your shop's needs.

SAMPLE SERVICE RATES
(BASED ON A SHOP SERVICE RATE OF $60/HOUR)

ITEM	PROCEDURE	TIME	PRICE
Aerobar	Install (no tape)	:20	$20.00
Baby Seat	Install	:20	$20.00
Bar Ends	Install	:07	$6.50
Bicycle Assemble	(from shipping)	:25	$25.00
Bicycle Disassemble	(for shipping)	:30	$30.00
Bicycle Tune-up	(multi-speed)	1.0	$60.00
Bicycle Tune-up	(one-speed)	:35	$35.00
Bicycle	Complete Overhaul	2:05	$125.00
Bottle Cage	Install	:02	$2.00
Bottom Bracket	Adjust	:10	$10.00
Bottom Bracket	Overhaul(cup & cone)	:25	$25.00
Bottom Bracket	Replace (cartridge)	:20	$20.00
Brake (one)	Adjust	:08	$8.00
Brake	Bleed	:20	$20.00
Brake	Install Disk Brake	:40	$40.00
Brake	Install Linear/Canti	:30	$30.00
Brake Pads	Replace	:15	$15.00
Cables	Replace w/Housing	:15	$15.00
Cables	Replace Rotor/Gyro	:20	$20.00
Chain	Replace	:10	$10.00
Chainrings (double)	Replace	:20	$20.00
Chainrings (triple)	Replace	:25	$25.00
Computer(w/o cadence)	Install	:15	$15.00
Computer(with cadence)	Install	:20	$20.00

ITEM	PROCEDURE	TIME	PRICE
Derailleur	Adjust	:08	$8.00
Derailleur	Replace	:15	$15.00
Fenders	Install	:15	$15.00
Fork Check	Alignment	:45	$45.00
Fork Align	Dropouts	:10	$10.00
Fork	Replace	:40	$40.00
Fork	Replace Oil/Overhaul	:40-:60	$40-$60
Frame Align	Dropouts	:10	$10.00
Frame Align	Gear Hanger	:12	$12.00
Frame Check	Alignment	:20	$20.00
Frame	Chase/Tap Braze-ons	:20	$20.00
Frame	Helicoil Derailleur Hanger	:30	$30.00
Frame	Chase/Face Bottom Bracket	:45	$45.00
Frame	Ream/Face Headtube	:35	$35.00
Frame, Custom	Assemble	3:00	$180.00
Freewheel	Remove and Replace	:10	$10.00
Handlebar	Tape	:15	$15.00
Handlebar, mountain	Cut Down (off bike)	:8	$8.00
Handlebar, mountain	Cut Down (on bike)	:10	$10.00
Handlebar, mountain	Replace	:20	$20.00
Handlebar, road	Replace	:30	$35.00
Headset	Overhaul	:30	$30.00
Headset	Replace	:40	$40.00
Headset	Adjust	:08	$8.00
Hub, 3 speed	Overhaul	:40	$40.00
Hub, coaster brake	Overhaul	:30	$30.00

United Bicycle Institute

ITEM	PROCEDURE	TIME	PRICE
Hub, front	Overhaul	:15	$15.00
Hub, rear	Overhaul	:20	$20.00
Hub	Adjust	:10	$10.00
Kickstand	Install	:05	$5.00
Pedals, pair	Overhaul	:25	$25.00
Pedals, pair	Install	:05	$5.00
Rack, front or rear (bike)	Install	:15	$15.00
Shifters	Replace (MTB)	:30	$30.00
Shifters	Replace (STI)each	:30	$30.00
Stem	Install	:20	$20.00
Suspension	Set-up/Adjust	:15	$15.00
Tire/Tube, front	Replace	:06	$6.00
Tire/Tube, rear	Replace	:07	$7.00
Tire/Tube, off bike	Replace	:05	$5.00
Toe clips/Straps	Install	:08	$8.00
Training Wheels	Install	:10	$10.00
Wheel	Build	:45	$45.00
Wheel	True/Replace Spoke	:15	$15.00

All of these service rates are based upon the actual time it takes to do the individual procedure. You must add on additional procedures if extra removal of components is necessary to start your work.

The remaining information in this chapter is reprinted by permission of the National Bicycle Dealers Association (NBDA). You may find it a useful initial guide to your planning process if you are thinking about opening a bike shop.

SO YOU WANT TO START A BICYCLE SHOP

A Message from the National Bicycle Dealers Association

The National Bicycle Dealers Association (NBDA) regularly receives requests from people interested in starting their own retail bicycle businesses. Our message can be broken into two parts: Good News and Bad News.

THE BAD

We'd be remiss if we didn't try to scare you off from the difficult task of starting a retail bicycle business. So here goes: Retailing is difficult, and it's getting tougher. If we told you that you'd go broke, we'd be right 70% of the time. The United States is in the midst of a revolution in retailing, with mass merchants, mail order, the Internet, chains, and other forms of selling gaining momentum, and small independent stores under tremendous pressure. Today's consumer wants high quality, great personal service, and a super-low price. There isn't much room for error, and the small store's costs are usually higher than the big guy's. It's tough to compete.

The number of independent bicycle dealers is dropping, from a high of about 8,000 in the early 1980s to 4,200 as of 2010. The bicycle retail industry typically loses about 1,000 bicycle dealers each year, mostly start-ups, but gains that many back because of even more start-ups. Many people have lost their life's savings in the retail bicycle business because they only loved bikes, but didn't have a similar zest for the art of retailing. Bike shops run by people who are only bicycle hobbyists, and not business people, typically find the going tough in today's competitive market. There is a high mortality rate of start-ups, and studies have shown that about 70% of new retail businesses in all industries don't last the first three years.

Add all that to the overall slim profitability in the bicycle industry, and you can really get depressed. NBDA studies show the typical bicycle dealer needs about a 36% profit margin to cover the costs of doing business and break even financially. Studies also show the average realized profit margin on bicycles to be around 36%, which is a break-even proposition devoid of profit. Fortunately accessories products generally carry a higher profit margin than bicycles. Still, the average bike dealer's profit is only 5% at year's end. -- about $25,000 for an average size store of $500,000 in annual sales.

THE GOOD

The level of innovation and diversity has never been higher in "dealer-quality" bicycle products. The number of entrepreneurial companies designing and manufacturing appealing products for the public is high, both in bicycles and accessories items. There isn't any part on a bicycle which hasn't been improved in the last five or so years. The bicycle is tied to health, vitality, fun and exercise. The bicycle is the least-expensive realistic transportation available. The bicycle affects peoples' lives in very positive ways, and its use contributes to the betterment of the environment.

Cycling participation is solid. There are approximately 45 million "cyclists" age 7 and older today, and cycling ranks fifth on the list of most popular outdoor recreational activities. The government has started to include bicycles in transportation planning. And for the retailer, the opportunity to successfully operate your own business in this very special field can be personally very satisfying.

SOME ADVICE

Look closely at yourself before taking on the difficult task of starting a bicycle business. Enthusiasm is important, but it's not enough. Make sure you can muster excitement and creativity for merchandising, buying strategies, accounting, inventory control, advertising, employee relations, and sweeping the floors. You must want to serve people of all ages, types, colors and creeds. You'll need some mechanical inclination and a strong constitution - not flinching from long hours, hard work and setbacks.

Use all the resources you can find to learn about small business basics. "Seat of the pants" business management principles can get you into a lot of trouble. Above all else, take the time to do your research and build a sound business plan. Planning, organizational skills, and high energy are prerequisites for survival in the bicycle business.

The most successful dealers in the country stress personal service, and developing personal relationships with customers based on caring and service. Quality and personal attention are the best ways to differentiate yourself from the various discounters and mail order outfits competing for the cycling dollar. The owner and key managers must truly want to help customers and the community, and be truly concerned about and involved with them.

This model of service affects almost every decision made by a retailer. Each time a customer steps into your store, he or she is entering the world of theater. You and your store are performing, and the showroom is your stage for showing product in interesting ways, where you interact with customers, and try to find out what they need and want that you can provide.

Each time a customer visits a store, he or she evaluates the experience itself. The successful dealer pays very close attention to the quality of the customer's "retail experience." Customers don't like to be ignored, or taken for granted, or manipulated, or bored. Attention to detail, good selection, knowledge, a caring attitude, good product presentation - these are all keys to giving the customer that good experience. The retailer him/herself must strive to become the brand in the community. Relying on the specific products you sell for your identity is extremely risky.

None of this is possible without being profitable, having the resources to meet customer expectations and wants. A common scenario of a struggling dealer is one who fails to maintain appropriate profit margins. The NBDA urges all dealers to keep records and know what their true cost of doing business is (rent, utilities, salaries, etc.) The numbers here are from the NBDA Cost of Doing Business Survey, reporting dealerships with expenses shown as a percentage of gross sales. It's simple arithmetic - if your sales don't cover your cost of goods plus your expenses, you're losing money. Know what YOUR break-even point is. Be in control.

AVERAGE EXPENSES FOR SPECIALTY BICYCLE RETAILERS

(From NBDA Cost of Doing Business Survey, expressed as a percentage of gross annual sales)

Payroll Expenses - 20.5%
Occupancy Expenses - 7.7%
Advertising/Promotion - 3.0%
Auto and Delivery - 0.5%
Depreciation - 0.9%
Insurance - 0.8%
Licenses/Other Taxes - 0.5%
Professional Services - 0.5%
Office Supplies/Postage - 1.2%
Telephone - 0.6%
Travel/Entertainment - 0.4%
Other operating expenses - 1.3%

TOTAL OPERATING EXPENSES - 37.7%
NET INCOME BEFORE TAX - 4.2%

GROSS MARGIN ON BICYCLE SALES - 36%
GROSS MARGIN ON CLOTHING SALES - 43%
GROSS MARGIN OTHER EQUPT. - 48.1%
GROSS MARGIN OTHER EQUPT. - 46.6%

Answering the Hard Questions in Business Plans

These are some examples of questions that should be addressed prior to deciding on opening or buying a bike shop. These are provided by Ed Benjamin on the NDBA website.

Goals and Lifestyle:

1. *What are your personal, long and short-term goals? Describe them in both lifestyle and dollar terms.*

2. *How long will the contemplated business serve these goals?*

3. *What is unique about you or your situation that will enable you to be successful at this business?*

4. *How much money do you have to invest?*

5. *What would be the consequences of losing that money?*

6. *What about this business would make it attractive to other investors?*

7. *What return do you expect?*

8. *What return do you think your investors (if any) will expect?*

9. *Where is your expertise?*

10. *What do you like to do the most?*

11. *What do you like to do the least?*

12. *In what areas do you need other's expertise?*

13. *Are you willing to work longer, harder hours?*

14. *Are you willing to work weekends?*

15. *Are you willing to forgo vacations, or time off, perhaps for years?*

16. *How will longer, harder hours, and fewer holidays affect your family or other relationships?*

17. *Who will help you?*

18. *How will you feel if your business is not successful?*

19. *What will you do, if your business is not successful?*

Research:

1. *What is the population within a 15-minute drive?*

2. *What is the income, and age demographics of that population?*

3. *What sort of bicycle facilities such as bicycle paths, BMX tracks, etc. exist?*

4. *What is the economic base of the community?*

5. *How many bike shops exist in the area?*

6. *How well are they doing?*

7. *How big is the local bicycle club(s)?*

8. *Are there local races promoted in the area?*

9. *Is there a local trail advocacy group in the area?*

10. *How rapidly is the community growing (or not)?*

11. *What bicycle brands are represented by local shops already?*

12. *What brands are not represented?*

13. *Have you compiled an analysis of each bike shop? (including years in business, size of store, number of employees, volume of sales)*

14. *Have you talked with the local reps for any of the bike lines?*

15. *Have you considered franchising?*

16. *Have you considered buying an existing store?*

17. *Have you talked to the staff of existing stores?*

18. *Have you considered hiring any of them?*

19. *Check the yellow pages, add to this information: clippings of newspaper ads and notes about any advertising the other bike shops are doing. What conclusions have you come to about advertising in this market?*

20. *Have you subscribed to the bicycle trade magazines?*

21. *What trade shows have you attended?*

22. *Have you acquired the NBDA studies on the bike business?*

23. *Have you investigated banks; do you have a potential line of credit arranged?*

24. *Do you qualify for any Federal or State assistance programs?*

25. Have you investigated SBA loans?

26. Have you talked to merchants in similar businesses, in the local community, about their business experiences?

27. Do you have a mentor(s) that can help you with the bike business?

28. Do you have a CPA and a lawyer that you are comfortable with, and who have successfully worked with other small merchants for many years?

29. Do you have an insurance agent and advertising agency (or consultant) that you are comfortable with, and have successfully worked with other small merchants for many years?

30. What market share do you think existing shops have?

31. Have you made a list of every place that sells bikes in the area? (include grocery stores, sporting goods, bike shops, hardware stores, used bicycle outlets, everything)

32. What complaints do local cyclists have about existing stores?

33. Are any local stores part of a bicycle store chain?

34. Are any local shops involved with Catalyst Super Sale?

Planning:

1. Have you defined your business in 50 words or less?

2. What will you name your business?

3. Are you convinced that business planning is an absolute necessity?

4. Have you made a financial plan that defines the capital you will need, projects your sales and projects your profits?

5. Do you have a computer? Are you competent with spreadsheets?

6. What business structure do you plan to use?

7. Have you prepared your current financial statements?

8. What is your current personal credit rating?

9. Do you have substantial personal assets to collateralize loans to the business?

10. What is your marketing plan?

11. What is your mission statement?

12. What trends in this business are forecast for the nation?

13. *What plans do you have to acquire additional training for yourself?*

14. *How will you train your staff?*

15. *What vulnerabilities do you think you will have? What are your plans to deal with them?*

16. *Are there plans by local or state government that will affect your business? (Example: widening a road in front of the site).*

17. *What is happening with the increase or decrease in suppliers to the bike business?*

18. *How do you expect to exit this business? (Sell it, liquidate it, die, etc.)*

19. *Have you investigated possible alternative locations?*

20. *Describe the basic lease terms offered or purchase price.*

21. *Have you talked to merchants who rent from this landlord, or are in the same immediate area about their experiences?*

22. *What marketing position do you expect to occupy?*

Now take the information that you have accumulated by answering these questions and:

1. *Describe the present situation of yourself and the market you want to enter.*

2. *Describe your objectives in starting this business, and how you will know if you reach them.*

3. *Describe the management team and organization you will create.*

4. *Describe the products you will offer, both merchandise and service.*

5. *Describe what equipment and facilities you will need*

6. *Analyze and describe the market.*

7. *Describe your marketing strategy.*

8. *Using a spreadsheet, create cash flow projections for five years.*

9. *Review all of the above, and write an executive summary.*

ADDITIONAL BUSINESS RESOURCES

Principles of Bicycle Retailing III by Randy Kirk. Available from the NBDA for $20 ($10 for NBDA members), or from Info Net Publishing, 949-489-9292.

The Interbike Directory, a complete directory to industry suppliers, $75 (or free to NBDA members) from Interbike, P.O. Box 1899, Laguna Beach, CA 92651; phone 949-376-6161, fax 949-497-9502.

The Complete Guide to Bicycle Store Operations, by Ed Benjamin, is a manual with CD-ROM that allows customization by the user. The manual covers a wide variety of subjects, including employee procedures, staff training, sales, rentals, cash drawer procedures, personnel, emergencies, service, housekeeping, shipping, security and more. $106 from the NBDA ($86 for NBDA members).

The NBDA Cost of Doing Business Survey, from the NBDA for $150 ($75 for NBDA members). Detailed financial study of bicycle retailing, complete with average costs, profit margins and more. The NBDA has completed four cost surveys; the most recent was published in 2002.

Repeat Business, by Larry W. Dennis. $11.95

Interbike Trade Expo, held in late September or early October in Las Vegas, Nevada. The show is open to the trade only. www.interbike.com

TRADE JOURNALS, TRADE ASSOCIATIONS AND ADVOCACY GROUPS

Bicycle Product Suppliers Association

(303) 442-2466
740 34th St.
Boulder, CO 80303
www.bpsa.org

Bicycle Retailer and Industry News

(949) 206-1677
25431 Cabot Rd., Suite 204
Laguna Hills, CA 92653
www.bicycleretailer.com

Bike-alog

(800) 962-1950
4105 E. Florida Ave.
Denver, CO 80222
www.bikealog.com

Bikes Belong Coalition

(303)449-4893
P.O. Box 2359
Boulder, CO 80306
www.bikesbelong.org

International Bicycle Expo (Interbike)

Interbike International Bicycle Expo
Nielsen Expositions
31910 Del Obispo St., Ste. 200
San juan Capistrano, CA 92675
www.interbike.com

International Mountain Bike Association

(303) 545-9011
207 Canyon, Suite 301
Boulder, CO 80302
www.imba.com

League of American Bicyclists

(202) 822-1333
1612 K Street NW, Suite 510
Washington, DC 20006
www.bikeleague.org

MTBaccess

P.O. Box 64097
Tucson, AZ 85728
www.mtbaccess.org

National Bicycle Dealers Association

(949) 722-6909
3176 Pullman St.#117
Costa Mesa, CA 92626
www.nbda.com

Alliance for Biking and Walking (formerly Thunderhead Alliance)

(202) 449-9692
P.O. Box 65150
Washington, D.C. 20035
www.peoplepoweredmovement.org

USA Cycling

(719) 434-4200
USA Cycling
210 USA Cycling Point
Colorado Springs, CO 80909
www.usacycling.org

Appendix

New Bike Assembly Checklist

UNITED BICYCLE INSTITUTE CHECKLIST

Here at UBI, we use a fairly comprehensive, multi-page checklist. The step-by-step procedures outlined on the checklist reflect our own combined experience in assembling thousands of bicycles over the last three decades. This list can serve as a starting point for developing a custom checklist for any bicycle shop. As a UBI graduate, feel free to copy, modify, or completely rewrite the following checklist to suit your needs.

It is important as you assemble the bicycle that you follow the step-by-step instructions in the checklist exactly. There are sections in the list that are procedural in nature. Failure to perform some of the steps in the proper sequence will produce incomplete results, which may require you to start the procedure over from the beginning. This will cost you valuable time.

One final note about the checklist: its layout is based on a classroom environment. Note that each component group is divided into sections.

United Bicycle Institute

New Bike Assembly Check List

Make/Model ______________________________ Size ________

Color ________ Inventory Number _________________________

Unpack Bike

- ❑ Remove inventory control number from carton and attach to the bike.
- ❑ Check seat tube for burrs.
- ❑ Install seat post to maximum height line. Be sure to grease seat post and seat tube.
- ❑ Clamp bike in repair stand by seat post only.
- ❑ Grease and install quill stem to maximum height line. Snug in place: do not torque yet! If threadless, install stem but do not torque bolts yet.

- ☐ Carefully remove protective wrap and discard.
- ☐ Check for damage and missing parts.
- ☐ Open accessory box and inventory contents.
- ☐ Check carton for loose parts.
- ☐ Remove rear wheel from bicycle.
- ☐ Recycle or discard bike box.
- ☐ Record serial number (found underneath bottom bracket shell):

____

Frame

- ☐ Check fork dropout alignment.
- ☐ Check rear dropout alignment.
- ☐ Check rear triangle alignment with Park Frame Alignment Gauge.
- ☐ Measure rear dropout spacing ____ and rear hub over locknut dimension______, compare.
- ☐ Measure ft. dropout spacing ____and ft. hub over locknut dimension_____, compare.

Wheels

- ☐ Remove tires and tubes from both wheels.
- ☐ Remove "rubber band" style rim strips. If plastic, leave on wheel. If freewheel equipped, remove freewheel and grease threads.
- ☐ Tighten rear hub drive side locknut and cone. Then reinstall freewheel. If cassette equipped, remove, grease and re-torque the lock-ring to manufacturer's specification.
- ☐ True front and rear wheels on truing stand using a tightly fitting spoke wrench. Check radial true, lateral true, dish and spoke tension and stress relieve.
- ☐ Adjust hub bearings. For hollow axles, adjust for a small amount of play.
- ☐ Grease full length of quick release skewers (do not remove safety warnings) and install into axle.
- ☐ Check wheels in dropouts for final hub adjustment. Quick releases should be completely closed. Readjust if necessary. When correct, remove wheels.

- ❑ Reinstall rim strips (if removed) and tubes and tires centering label over valve with label facing right, unless rotation direction on tire indicates otherwise.
- ❑ Check that tire bead is properly seated and inflate to maximum pressure as printed on the sidewall.

Bottom Bracket

- ❑ Remove crank arm dust caps, if applicable.
- ❑ Remove crank bolts/nuts and washers. Make sure washers have been removed!
- ❑ Remove cranks using the appropriate crank extractor.
- ❑ Check chainring bolts for tightness, if applicable.

If bicycle has a conventional loose ball, cup and cone bearing system do the following:

- ❑ Loosen lockring, but do not remove.
- ❑ Loosen adjustable cup and back out a few turns; do not remove.
- ❑ Grease threads on adjustable cup.
- ❑ Back out fixed cup a few turns and apply grease to fixed cup threads.
- ❑ Tighten fixed cup to appropriate torque to manufacturer's specifications.
- ❑ Adjust bearings, starting with extra play and adjusting until play barely disappears.

If bicycle has a sealed cartridge bottom bracket, do the following:

- ❑ Back out fixed cup a few turns and apply grease to fixed cup threads, per shop's specifications.
- ❑ Tighten fixed cup to appropriate torque to manufacturer's specifications.

For all four sided spindle bottom brackets, do the following:

- ❑ Clean bottom bracket spindle flats and crank arm holes. They must be clean and dry. Use degreaser or rubbing alcohol with a clean rag.
- ❑ Install right crank arm, checking all four positions on spindle to find the most aligned position.
- ❑ Be sure to grease crank arm bolt or nut threads and washer, if applicable.
- ❑ Torque to manufacturer's specifications.

- ❑ Recheck bearing adjustment using right crank arm for leverage.

For Spline Spindle Bottom Brackets, do the following:

- ❑ Lightly grease splines and then reinstall crank arms. Be careful to align the splines on the spindle with the crank arms!
- ❑ Torque to: Shimano Octalink 300-432 (34-49 Nm) or ISIS 336-372 in. lbs (38-42 Nm). If spindle is not Shimano or ISIS, torque to manufac turer's specifications

All Bottom Brackets:

- ❑ Install left crank arm.
- ❑ Be sure to grease crank arm bolt or nut threads. Grease washer, if applicable.
- ❑ Torque to to manufacturer's specifications. If provided, install toe clips, straps and reflectors on pedals.
- ❑ Grease threads on pedals and install to proper torque 300-350 in. lbs (34-40 Nm).

Headset

Turn fork slowly and check for abnormal roughness (possibility of improper assembly, or a bent or upside down bearing retainer).

If bicycle has a conventional threaded headset, do the following:

- ❑ Remove headset locknut.
- ❑ Grease threads and reinstall locknut.
- ❑ If not already installed, grease and install quill stem to maximum height line, torque to manufacturer's specifications.
- ❑ Adjust headset bearings, starting with play and adjusting until play barely disappears.

If bicycle has a threadless headset, do the following:

- ❑ Wipe outside portion of steerer tube that contacts stem, as well as the inside of the stem with a clean shop rag. The stem and steerer must be clean and free of debris.
- ❑ Install spacers, if provided.
- ❑ Be sure fork is seated firmly, then seat stem firmly against headset spacers.

- ❑ Verify that the gap between the top of steerer tube and top of stem is 3 - 5mm.
- ❑ Grease top cap bolt and install top cap into top of stem and steerer tube.
- ❑ Adjust headset bearings, align stem and tighten stem binder bolts to manufacturer's specification.
- ❑ If not already installed, install handlebars, brake and shift levers.
- ❑ If not already installed, install grips or tape, and bar ends, if provided.

Setting Handlebar and Brake Lever Angles:

- ❑ Flat handlebar: Set tipped slightly up and back from horizontal.
- ❑ Set brake levers at 45° to ground.
- ❑ Riser handlebar: Set tipped slightly forward from vertical.
- ❑ Set brake levers at 30° from ground.
- ❑ Drop handlebar: Set bottom of drops horizontal to ground.

Brakes

All Brakes:

- ❑ Turn lever and/or caliper barrel adjuster threads out a few turns and grease the threads.
- ❑ Thread barrel adjusters all the way back in or leave 2 threads showing.
- ❑ Install wheels with quick releases properly tightened.
- ❑ Seat wheels properly in dropouts and center in frame.
- ❑ If cables are pre-installed, carefully remove cables from housing, leave attached to brake levers.
- ❑ Grease brake cables and reinstall into housing.
- ❑ Be sure to grease all cable anchor bolts.

Linear Pull Only:

- ❑ Verify brake arms pivot freely. Lubricate pivots with wet lube.
- ❑ Disengage spring on brake arms.
- ❑ Verify brake arms are parallel. If not, switch brake shoe post spacers accordingly.
- ❑ Check for recommended noodle carrier to brake arm distance of 39 - 65mm, or as recommended by manufacturer.

Be sure to adhere to the following guidelines when setting up brake shoes:

- ☐ Shoe Height: Pad should contact rim at the center of the braking track.
- ☐ Shoe Toe-in: There should be a .5 - 1.5mm gap at the rear of the pad just as the front makes contact with the rim.
- ☐ Shoe Angle: Shoe should follow the contour of the rim.
- ☐ Shoe Interface: Shoe should contact rim squarely.

Linear Pull Only:

- ☐ Install accordion boot on cable.

All Brakes:

- ☐ Re-anchor cables and torque to manufacturer's specification.

Final Brake Check and Failure Test:

- ☐ Stress cables and seat the housing system by squeezing the brake levers several times. This will ensure that all fixing bolts are tightened properly and there are no flaws in the system.
- ☐ When finished pre-stretching, lever travel should not exceed two thirds of its full travel to the handlebars.
- ☐ Shoe Clearance: Check pad to rim clearance, pads should be 1 - 2mm from rim on each side.
- ☐ Shoe Centering: Brakes should be centered and both brakes feel the same at the lever.

Derailleurs

- ☐ If cables are pre-installed, loosen derailleur anchor bolts and leave attached to shift levers.
- ☐ Grease derailleur cables as instructed. Do not tighten into derailleur cable fixing bolt yet!
- ☐ Make sure shift levers are in their neutral position.
- ☐ Hold each cable end while shifting through all lever indexes, making sure cable moves freely without drag.
- ☐ Remove front derailleur clamp bolt, grease the threads and reinstall.
- ☐ Check and adjust front derailleur cage height and angle.

- ❑ Bottom of outside cage should be 1-3mm above highest point of large chainring.
- ❑ Cage angle should be parallel to large chainring.
- ❑ Torque front derailleur clamp bolt to manufacturer's specification.
- ❑ Remove the rear derailleur.
- ❑ Using the derailleur hanger alignment tool, check against the wheel for misalignment.
- ❑ Grease hanger bolt threads and reinstall. Torque bolt to manufacturer's specification. Avoid trapping angle adjustment screw against face of derailleur hanger.

Rear Derailleur

- ❑ Install rear derailleur cable behind cable fixing washer. Do not install front cable yet.
- ❑ Grease cable fixing bolt threads and seat cable in groove under the cable-fixing washer.
- ❑ Adjust rear derailleur high limit screw so the guide pulley is aligned under the smallest rear cog.
- ❑ Unthread adjusting barrel four turns. Apply wet lube and thread all the way in.
- ❑ Torque cable fixing bolt to manufacturer's specifications.

Rear Derailleur Index Adjustment:

- ❑ Beginning with the chain positioned in the smallest cog (in highest gear) shift into next position cog while turning cranks (one click at the shift lever only). Guide pulley should now be centered directly under the next position cog.
- ❑ If shift lever clicks but chain does not shift, shift back to first cog, loosen fixing bolt, pull out cable slack and retighten fixing bolt. Shift again to the next position cog.
- ❑ If chain shifts, but makes noise on next position cog, derailleur is moving too far. Turn barrel adjuster clockwise until noise disappears. Shift through rear cog set while pedaling. Use barrel adjuster to correct cable tension, if neces sary, until derailleur shifts quietly and responsively.
- ❑ Shift to largest cog (in lowest gear) and adjust rear derailleur low limit screw so the guide pulley is centered under the largest rear cog.

- ❑ Shift again through all cogs and use barrel adjuster as needed.

Front Derailleur

- ❑ Position chain in the lowest gear (large rear cog and small chainring). Chain should be all the way inboard on the bicycle.
- ❑ Adjust front derailleur low limit screw so there is a 1mm gap between the inner cage plate of the derailleur and chain.
- ❑ Install front derailleur cable behind the cable fixing washer and passing over the cable guide "tab", if so designed.
- ❑ Grease cable fixing bolt threads and seat cable in groove under cable fixing washer.
- ❑ Torque cable fixing bolt to manufacturer's specifications.

Front Derailleur Index Adjustment:

- ❑ Starting with chain in lowest gear (large rear cog and small chainring), shift chain onto middle chainring by pushing on front lever one click while turning cranks.
- ❑ If shift lever clicks but chain does not shift, downshift, loosen cable fixing bolt, pull out excessive cable slack, and retighten.
- ❑ If chain shifts, but inner cage plate rubs chain, turn the barrel adjuster on the lever inward until rubbing just disappears. If cage doesn't move inboard, downshift into neutral position, loosen cable fixing bolt, turn crank to allow chain to drop onto small chainring. Check inner cage/chain gap (1mm) and route of cable over guide tab. Retighten anchor bolt, then repeat the previous step.
- ❑ Shift rear derailleur so that chain is in smallest cog (high gear) and shift front derailleur from the middle chainring into the large chainring. Chain should not rub on outer cage plate.
- ❑ If chain is unable to shift into the large chainring, first check front derailleur high limit screw for proper adjustment, then check cable tension. There may be too much slack in the cable to allow full derailleur travel. Downshift to neutral position while pedaling and check for slack. Loosen cable-fixing bolt, pull slack from cable and re-anchor cable, repeat the previous step. Readjust barrel adjuster as necessary.
- ❑ If problems persist, recheck to make certain you routed the cable properly over the cable guide "tab" if so designed.

- ❑ Position chain in the highest gear. Chain should be all the way outboard on the bicycle.
- ❑ Adjust front derailleur high limit screw so there is a 1mm gap between the inside of the outer cage plate and the chain.

Final Derailleur Adjustment and Fine Tuning:

- ❑ Shift through all possible gear combinations and fine tune front and rear derailleur adjustments, if necessary.
- ❑ Fine tune limit screws as needed.
- ❑ Fine tune barrel adjustments and cable tension as needed.

Finish

- ❑ Trim and cap all cables.
- ❑ Install saddle so that saddle is level and centered on rails. Be certain seat rail binder bolt is greased and torque to manufacturer's specification.
- ❑ Install all remaining reflectors supplied by the manufacturer. If rear reflector is seat post mounted, install at top.
- ❑ Install any remaining accessories as instructed.
- ❑ Perform a complete safety check on bicycle.
- ❑ Check brakes by firmly squeezing levers several times.
- ❑ Check tightness of stem, handlebars, control levers, seat post and saddle.
- ❑ Check tightness of front and rear quick release skewers and/or axle lock nuts
- ❑ Check bearing adjustment of hubs, bottom bracket and headset.

Test Ride

- ❑ Test ride bicycle.
- ❑ Shift through all gear combinations.
- ❑ Observe for handlebar alignment.
- ❑ Thoroughly test brakes.

Do not ride off road! Keep the bike clean and new looking!

After Test Ride

- ❑ Recheck all bearing adjustments and adjust as necessary.

- ❑ Re-torque crank bolts, handlebar and stem binder bolts.
- ❑ Readjust brakes and/or derailleurs if necessary.
- ❑ Recheck wheel trueness.
- ❑ Clean bicycle thoroughly using a clean rag.

Torque Specification Conversions

Multiply	By	To Get
Foot pounds	12	Inch pounds
Foot pounds	1.3558	Nm
Foot pounds	13.826	Kgf-cm
Inch pounds	0.083	Foot pounds
Inch pounds	0.113	Nm
Inch pounds	1.152	Kgf-cm
Nm	0.738	Foot pounds
Nm	8.851	Inch pounds
Nm	10.2	Kgf-cm
Kgf-cm	0.072	Foot pounds
Kgf-cm	0.868	Inch pounds
Kgf-cm	0.098	Nm

Most Common Bolt Circle Diameter Measurements

Crankset Style	Bolt Cirle Diameter	Hole Center to Center
Road bike double (both chainrings)	130mm	76.4mm
Road bike Campagnolo (double)	135mm	79.4mm
Road bike Campagnolo (middle/outer)	135mm	79.4mm
Road bike Campagnolo (inner)	74mm	43.5mm
Standard MTB/Touring triple(middle/outer)	110mm	64.7mm
Standard MTB/Touring triple (inner)	74mm	43.5mm
Micro drive MTB/Touring triple (middle/outer)	94mm	55.3mm
Micro drive MTB/Touring triple (inner)	56mm	32.9mm
Compact drive MTB/Touring triple (middle/outer)	94mm	55.3mmm
Compact drive MTB/Touring triple (inner)	58mm	34.1mm
2003 Shimano XTR (outer)	146mm	
2003 Shimano XTR (middle)	102mm	
Pre-'03 Shimano XTR 4 arm (middle/outer)	112mm	NA
Pre-'03 Shimano XTR 4 arm (inner)	68mm	NA
Shimano LX/Deore/XT 4 arm mega 9 (middle/outer)	104mm	NA
Shimano LX/Deore/XT 4 arm mega 9 (inner)	64mm	NA
Track	144mm	
Compact road	110mm	

Glossary

The following glossary defines terms as they are commonly used in the bike industry.

3-2.5 Titanium: Titanium alloy with 3% aluminum and 2 1/2% vanadium

6-4 Titanium: Titanium alloy with 6% aluminum and 4% vanadium

A.S.T.M.: American Society for Testing and Materials

Adjustable cup: Bottom bracket bearing cup, which is part of a serviceable loose ball bearing bottom bracket, that threads into the non-drive side of the frame and is held in place by a lockring and houses either loose ball bearings or bearings held by a retainer

Aero spoke: Spoke that is oval shaped to reduce aerodynamic drag, with a leading edge that is larger than the trailing edge, similar to an airplane wing

Air damper: Damper that utilizes air as the damping medium

Air piston: Platform attached to a shaft that moves when the suspension is compressed and pushes against the pressurized air chamber

Air spring: System that utilizes a pressurized air chamber to provide resistance against compressive forces

Alloy: Any number of substances having metallic properties and consisting of two or more metallic elements

Aluminum: Element number 13 on the periodic table. Used in the bicycle industry with different alloying elements depending on the application (frames, handlebars, components, etc.)

Angular contact full complement bearing: Ball bearing assembly that uses axially asymmetric races. An axial load passes in a straight line through the bearing, whereas a radial load takes an oblique path that tends to want to separate the races axially. So the angle of contact on the inner race is the same as that on the outer race. Angular contact bearings better support combined loads (loading in both the radial and axial directions) and the contact angle of the bearing should be matched to the relative proportions of each

Angular thrust load: Momentary force applied in a non-radial direction; for example, impacts absorbed by a headset

Atmosphere: Measure of air pressure, equal to 14.7 pounds per square inch. Also known as bar

Axle set: Hub axle parts kit consisting of axles, cones, spacers, locknuts and any sealing mechanism required

Ball track: Section of the bearing race which contacts the bearings. Also refers to a wear line on the bearing races

Band clamp: Mechanism used to attach a front derailleur to a seat tube or a control lever to a road drop handlebar

Barrel adjuster: Hollow bolt that a cable passes through allowing the increase or decrease of cable tension without re-anchoring the cable anchor bolt in a derailleur or brake system

BCD (bolt circle diameter): Diameter of an imaginary circle that passes through the center of chainring bolts or IS disc brake rotor bolts

Bead (tire): Wire or other synthetic material molded into the inside diameter of a tire that engages and secures the tire to the rim

Bearing retainer: Metal or plastic retainer that holds and separates a group of bearings

Bladed spoke: Spoke with a flat profile used to reduce wind resistance

Bleeding: The procedure for removing air or replacing old fluid in a hydraulic system

Body angle screw: The screw that adjusts the angle of the rear derailleur body, optimizing the distance between the guide pulley of the derailleur and a cog on the cassette. Also know as the b tension screw

Bonding: Joining by means of an adhesive

Bottom bracket: Bearing assembly that works in combination with the bottom bracket spindle to allow the crankset to rotate

Bottom bracket drop: The distance from the center of the bottom bracket shell to an imaginary line connecting the front and rear axle

Bottom bracket height: Distance from the center of the bottom bracket to the ground

Bottom bracket spindle: Spindle to which crankarms attach

Bottom out: Point at which a front fork or rear shock's travel is fully compressed

Brake arch: Supportive structure that connects the lower legs of a suspension fork together

Brake noodle: Curved metal tube which is used with a linear pull caliper that directs the brake cable from a vertical to a horizontal position

Brake pad: On a road brake caliper, the piece that attaches to the brake shoe, usually made of some type of rubber compound, which engages the sidewall of the rim causing the wheel to stop. On a disc brake, the piece that inserts into the caliper and engages the disc rotor under braking

Brake pad carrier/ brake shoe: Piece that holds the brake pad and attaches to the caliper

Brake post/boss: Stud for mounting cantilever, linear pull or u-brakes to a frame or fork

Brake reach: Distance from the brake mounting point to the center of the braking surface on the rim

Braze-on: Frame fitting such as water bottle boss, cable guide, etc. that is attached to the frame via brazing

Braze-on front derailleur: Derailleur that uses a radiused mounting plate that is either brazed on, welded on, bolted, or riveted to the seat tube of the bicycle

Brazing: Joining process that produces a coalescence of materials by heating them to a suitable temperature,. then adding dissimilar filler material, or filler, whose melting point is above 800° F but below the melting point of the parent material

BSD (bead seat diameter): Diameter of a rim where the tire bead engages the hook bead of the rim

Bumper: Cushion, usually made of elastomer, to prevent harsh contact of internal components

Bushing: Most commonly a ring of metal, sometimes with a friction reducing material coated on the inside. Used between the fork stanchions and sliders or shock shaft and seal head in suspension, between link bodies and pins in a chain as well as pedals and suspension pivots. Acts like a bearing.

Butted spoke: Spoke with varying diameter

Butting: Process of varying the wall thickness of a piece of tubing, over its length. Process is used in the manufacturing of frame tubes, spokes, and fork parts

Butyl rubber: Synthetic rubber made by polymerization of isoprene and isobutylene

Cable anchor bolt: Bolt used to secure a cable

Cable housing: Casing through which a cable is routed

Cage-style pedal: Pedal design in which the foot rests on top of a metal cage that attaches to the pedal spindle

Caliper brake: Any type of brake in which the mechanism has a jaw-like movement and a single mounting point to the frame or fork

Cantilever boss: Stud that is approximately 8mm in diameter that attaches to a frame or fork and which acts as a pivot for a cantilever type brake

Cantilever boss width: Center-to-center distance measurement of cantilever or u-brake posts

Cantilever brake: Type of brake that consists of two separate arms, each of which pivots around a post mounted to frame stays or fork blades

Carbon fiber: Commercial material made by pyrolyzing (a controlled burning process) any spun, felt, or woven raw material to a char at temperatures from 700° to 1800° C

Cartridge bearing: Self-contained bearing assembly consisting of an outer race, bearings (with or without retainer) and an inner race

Cartridge unit bottom bracket: Non-serviceable type of bottom bracket that is fully enclosed

Casing: Structural fabric of the tire

Cassette: Group of cogs that mount on a freehub

Center pull brake: Any type of brake where the mechanism is actuated from a central point via a brake cable

Center-to-flange: Measurement used during spoke length calculation. The measurement is from the center of the hub to the center of the flange on each side of the hub

Chainline: The imaginary line that runs through the center of the drive train and is parallel to an imaginary line than bisects the frame

Chainring: Cog or sprocket that mounts to the crankarm spider

Chainring bolt: Special bolt used to attach a chainring to the crank or another chainring

Chasing: Machining process used to repair/clean damaged threads of a bolted joint

Chromoly (chromium molybdenum): Steel alloy consisting of up to 1% carbon, 0.7% to 1.1% chromium, and 0.2% to 0.4% molybdenum. Also know as 4130

Clamp diameter: Measure of diameter of the clamp used to mount control levers to handlebars, or front derailleurs to seat tube

Clincher: Type of tire and rim system that mounts the tire to the rim by engaging a bead on the tire with a hook on the rim

Clipless pedal: Type of pedal in which a cleat that is attached to the sole of a shoe engages a retention mechanism integrated into the pedal

CNC (computer numeric control): Machining process which uses computer controlled cutting machines to manufacture components out of a solid stock

Coaster brake: Type of brake housed in the rear hub. The brake is activated by rearward rotation of the crankarms which engages a clutch mechanism inside the hubshell, pushing the brake shoes against the inner walls of the hub shell.

Cog: Sprocket used on a rear cassette or freewheel

Coil spring: Wound mechanical spring made of steel or titanium wire

Cold forged: To form a metal part into a desired shape by use of compressive force without heating the metal beyond 1/3 the temperature of its melting point

Commercially pure titanium: Titanium with no other alloying ingredients. Often abbreviated as CP

Compression: Pressing force applied to a spring or damper

Compression ring: Part of a bearing assembly used to align the race so that it is parallel with the other race and perpendicular to a threadless steerer tube or axle

Connecting pin: Specially designed pin used to join chain links together

Conrad bearing: Type of cartridge bearing in which the inner and outer races radially offset, so the races touch at one point and have a large gap on the radially opposite side. The bearing is filled by placing balls into the large gap, then distributing them around the bearing assembly using a retainer. The act of distributing the balls causes the inner and outer races to become concentric. Named for its inventor, Robert Conrad. Designed primarily for high RPM applications

Cottered crank: Type of three piece crank that utilizes a tapered wedge bolt, known as a cotter, to locate and attach the crank arms to the spindle

CPSC: Acronym for Consumer Product Safety Commission, U.S. government agency which mandates safety guidelines for consumer goods

Crown race: Part of the lower bearing assembly of a headset that is installed at the fork steerer tube directly above the fork crown

Cutting fluid: Lubricant used during machining

Damper piston: The part of the damper system that contains ports for the damping medium, i.e. oil or air to pass through

Damping: Regulation of the stroke in suspension through resistance caused by a medium passing through a piston

Derailleur: Mechanical devise that moves a chain from one cog or chainring to another

Direct pull (straight pull) spoke: Spoke that does not utilize a J-bend at the spoke/hub interface

Disc brake: Type of brake that utilizes a rotor which is mounted to the hub, and a piston type caliper mounted to the frame or fork

Disc brake caliper: Part of a disc brake system that houses the brake pads and mounts to the frame or fork

Disc brake mounting tab: Mounting points to affix a disc brake caliper to a frame or fork

Disc brake rotor: Metal disc attached to a specific type of hub which the disc brake pads engage in order to stop a wheel from rotating

Dishing: Process of centering the rim between the hub's locknuts by adjusting the spoke length and tension

DOT fluid: Specific engineered fluid designed to be used in hydraulic disc brake systems

Dropouts: The fixtures at the rear of the frame or end of the fork legs that the hub axle engages

Drum brake: Type of cable actuated brake that uses radially mounted brake shoes to engage the interior surface of a drum mounted to the hub

Dual crown fork (triple clamp): Type of suspension that utilizes two fork crowns, one above and one below the head tube

Dual pivot caliper: Brake caliper that has a single mounting point and two pivots points

Durometer: Term used to describe the relative hardness of rubber or plastic

Effective top tube length: Imaginary length of a top tube based on a horizontal line from the center of the top of the head tube to the center of the seat tube

Elastomer: Plastic polymer with spring-like qualities

Elongation: The increase in a material's length due to stress in tension or thermal expansion

ERD (effective rim diameter): Measurement taken from one nipple seat to another that are 180 degrees from each other. This measurement is a key component in correct spoke length calculations

E-type front derailleur: Front derailleur that uses a plate that is captured behind the drive side bottom bracket cup and the frame

Expander bolt: Bolt used to secure the height and the rotational alignment of a quill stem

Expander wedge: Part of a quill stem that works in conjunction with the expander bolt to secure the height and rotational alignment

Eyelet (rim component): Small steel insert that is formed around the spoke hole of a rim and offers support for the spoke/rim interface

Eyelet (suspension component): The end of a rear shock that uses mounting hardware to affix it to the frame or swingarm of a rear suspension bicycle

Facing: Process of machining the ends of a flat surface

Fade (brake): Reduction in friction between brake pad and braking surface caused by excessive heat build-up

Fade (suspension): Decrease in performance due to excessive heat build-up

Fatigue strength: The maximum stress a material can endure for a given number of stress cycles without breaking or permanently deforming

Ferrule: Metal or plastic cap that fits over the end of a cable housing

Fillet braze: Brazing process which uses a filler material to form an external reinforcement at an assembly point

Fixed cup: Bottom bracket bearing cup used in an adjustable loose ball bearing system that threads into the drive side of the frame and tightens against the face of the bottom bracket shell

Fixture: Apparatus used to hold parts rigidly during machining or manufacturing

Fork boot: Protective cover, typically for suspension fork stanchion tubes

Fork crown: Structural member of a fork that connects the steerer tube with the fork legs

Fork leg: Tubes connecting the dropouts to the crown of a fork

Freehub: Ratcheting drive mechanism that is an integral part of the rear hub

Freewheel: Cluster of cogs mounted on a ratcheting mechanism that threads onto the rear hub

Foot pound (ft. lb.): Unit of work or energy, equal to the work done by a force of one pound when its point of application is one foot from the axis of rotation

Full compliment bearing: Cartridge type bearing which is filled with the maximum number of bearings by eliminating the retainer

Guide pulley: The upper pulley located in the cage of a rear derailleur, which functions to guide the chain as it engages the cog

Handlebar drop: Measurement taken from the center of the flat top portion on a road handlebar to the center of bottom of the drop

Handlebar reach: Measurement taken from the center of the flat portion of a road handlebar to the center part of most forward reaching section of the drop, where the brake/shift levers mount

Handlebar rise: Vertical measurement taken from the center of the stem clamping area to the center of the handlebar grip area

Handlebar sweep: The amount, measured in degrees, that the ends of a handlebar angle back toward the rider

Head tube angle: Measured in degrees, the angle between the head tube and level ground. Generally steeper angles equate to quicker steering and shallower angles equate to slower steering

Head tube length: Measurement from the bottom to the top of the head tube, not including the headset

Headset bearing assembly: Located in the head tube of the frame, that is tasked with handling the rotation of the steering assembly

Headset stack height: Measurement of the portion of a headset assembly visible outside the frame, including top and bottom portions of the headset

Heat treatment: Heating and cooling a metal or alloy at a controlled temperature for a specified duration to obtain desired properties or conditions. Can be done with or without chemical additives

High limit screw: Mechanical adjuster that sets the stopping position for a derailleur as it moves away from the centerline of a frame

Hub: The central part of a wheel housing the axle and bearing assembly, from which the spokes radiate out toward the rim

Hub brake: Any type of brake that utilizes the hub as a part of the braking mechanism

Hub flange: Portion of a hub, which extends perpendicular from the axle, to which one end of the spoke is anchored

In. lbs. (inch pounds): Unit of work or energy, equal to the work done by a force of one pound when its point of application is one inch from the axis of rotation

Inner cage (front derailleur): The portion of the derailleur that moves the chain from a smaller chainring to a larger chainring, also works as a chain guide to keep the chain from falling off to the inside of the crankset during shifting

Inner cage (rear derailleur): The portion of the derailleur that houses the guide and tension pulleys, which is located closest to the spokes of the wheel

Integrated headset: Bearing assembly that does not use a traditional pressed cup to house the bearings, but utilizes a machined bearing seat in the head tube of the frame

Investment casting: Casting method designed to achieve high dimensional accuracy for small castings by making a mold of refractory slurry, which sets at room temperature, surrounding a wax pattern which is then melted out to leave a mold without joints

IS mount: Disc brake caliper mounting location, which uses bolt holes that are parallel to the axle, measuring 51mm center to center

ISO: International Organization for Standardization, an organization which develops and publishes international standards.

Jig: Apparatus used to hold parts during machining or manufacturing

Kevlar: Lightweight synthetic material that is extremely strong and supple. Primarily used as a bead on a folding tire, but also used in tire casings to help resist punctures and the corners of saddles due to its resistance to abrasion

Kgf-Cm (kilograms of force - centimeter): a measure of torque in which a unit of mass (1 Kg) has been converted to a unit of force by multiplying by the Earth's average gravitational value (9.81 m/s^2). See **torque**

Lateral truing: Making a rim straight from side to side by adjusting spoke tension

Latex: Protective fluid contained in the tissue beneath the bark of the rubber tree used in the production of natural and synthetic rubber

Linear pull brake: Type of cantilever brake in which the cable is pulled in a horizontal direction to activate the brake arms

Lock out: Feature that regulates oil flow to the point of drastically limiting suspension movement

Lockring: Threaded ring that secures a component

Low limit screw: Mechanical adjuster that sets the stopping position for a derailleur as it moves toward the centerline of a frame

Low working tension: When building a wheel, the point at which all the spoke nipples have started to seat against the spoke bed of the rim

Lowers: Lower legs of a telescoping suspension fork. Also referred to as **sliders**

Lug: Cast or bulge formed socket or series of sockets by which tubes are inserted and brazed to form a union or joint

Machining: Performing various cutting or grinding operations on a piece of work

Master cylinder: The hydraulic pump of a disc brake system that contains a cylinder and a piston, that is actuated by the brake lever, and supplies hydraulic fluid under pressure to the caliper at the wheel

Master link: Universal removable chain link used in the installation of a single speed chain

Matrix: Solid in which particles are held/embedded

MCU: Acronym for Micro Cellular Urethane, a type of elastomer used as a spring with damping properties. The MCU contains air bubbles to lessen distortion and cause a more predictable behavior

Melt forged: To form a metal part into a desired shape by heating it to just below its melting point and compressing the metal between two halves of a mold

Mineral oil: An engineered hydraulic fluid which is the fluid medium used in some hydraulic disc brake systems

MMPT or M: Abbreviation for millimeters per thread

Modulation: The fluctuation of energy application

Modulus of elasticity: Materials tendency to deform elastically, non-permanently, when a load is applied to it

Negative spring: Spring that offsets the stiction caused by tight o-ring seals. Negative springs can be a separate air chamber or a small coil spring. If adjustable, it can be used for tuning purposes

Newton: The metric standard measure of force, which is the amount of force required to accelerate a mass of one kilogram at a rate of one meter per second squared. Named after Sir Isaac Newton

Nipples: Wheel component that interacts with the threads of a spoke to allow for tension to be applied or adjust

Nm (Newton meters): Measure of torque, equal to one Newton of force acting on a one meter lever

Noodle carrier: Pivoting mechanism that is mounted on a linear pull brake arm to which the brake noodle attaches

OEM: Acronym for Original Equipment Manufacturer

OLD: (over locknut dimension) The distance on a hub from one locknut to the other. Also used when referring to the spacing between the dropouts of a frame or fork

One piece crank (Ashtabula): type of bicycle crank in which the arms and spindle are incorporated into one piece

Optimum tension: In wheel building, the spoke tension high enough to prevent spoke nipple from unwinding over the life of the wheel, but not too high to compromise the strength of the rim

Outer cage (front derailleur): the portion of the derailleur that moves the chain from a larger chainring to a smaller chainring, also working as a chain guide to keep the chain from falling off to the outside of the crankset during shifting

Outer cage (rear derailleur): the portion of the derailleur that houses the guide and tension pulleys, which is located furthest from the spokes of the wheel

Packing-up: term used to describe the ride characteristics of a rear shock or fork whose rebound is set too slow

PAN (polyacrylonitrile): precursor used in the manufacturer of carbon fiber

Pawl spring: type of spring that engages the pawl, to position the pawl to properly engage the ratchet teeth

Pawls: small pivoting teeth that engage a ratcheting mechanism. Usually used in freewheels, freehubs, internally geared hubs and shift mechanisms

Pinch flat (snake bite): flat tire that occurs when the tire is compressed so much that the inner tube is "pinched" between an obstacle and the top of the rims sidewall, usually identified by two small holes

Piston: Cylindrical piece that moves back and forth within a tube, receiving pressure from, or exerting pressure on, a fluid or a gas

Pitting: Small depressions that form in the ball track of a bearing race (cone or cup) due to misadjustment or contamination of the bearing assembly

Platform pedal: type of pedal designed to be used with flat, soft-soled shoes. The downhill/BMX variation provides a wide stable platform for the foot

Polyurethane rubber: synthetic resin elastomer made by the reaction of a diisocyanate to a polyester. Has a resistance to abrasion, oil, ozone, and high temperature

Post mount: disc brake caliper mounting location, which uses bolts that are perpendicular to the axle and are 74mm center to center

Precursor: raw material used in the manufacturer of carbon fiber

Press fit (interference fit): the joining of two items where the piece that is being inserted is intentionally over-sized compared to the piece that is housing the assembly

Pressed cup: part of a headset assembly that is pressed within the head tube of the frame by means of force

Presta valve: type of inflation valve developed by the French for use on bicycle inner tubes utilizing a knurled nut to close the valve

PTFE: abbreviation for polytetrafluorothylene, a white or gray paste-like material which can be used as a thread locking agent

Pulling spoke: a spoke that pulls the rim as the wheel rotates

Quill: the vertical extension of a stem used with a threaded headset system

Radial lacing: lacing spokes into a wheel which take a direct path from the hub to the rim without crossing any other spokes within the wheel

Radial load: load applied around the axis of a bearing assembly

Radial truing: making a rim round by adjusting spoke tension

Reaming: machining the inside diameter of a tube or hole

Rebound: the return stroke in a suspension system after it has been compressed

Recumbent: any bicycle designed to place the rider in a somewhat reclined, feet-forward position

Resin: Non-metallic disc brake pad material

Rim: The outer part of the wheel, attached to the hub via spokes, to which the tire is mounted

Rim brake: any type of brake that utilizes the rim sidewall as a braking surface

Rim strip: strip of cloth, rubber, or plastic used on clincher rims to protect the inner tube from being punctured by the spoke/nipples or rim drillings

Roller cam brake: type of brake using a long-arm cantilever design activated by a cam and pulley system

SAE: acronym for Society of Automotive Engineers

Scandium: element number 21 on the periodic table. As it pertains to the bicycle industry, an alloy of 99.5 - 99.9% aluminum, and 0.1 - 0.5% scandium typically used in frame tubes

Schraeder valve: type of valve commonly used on bicycle, motorcycle or automotive inner tubes and tires utilizing a spring actuated valve core

Seal head: part of a shock that contains an oil seal and bushing to support the damper shaft and close the damper system

Sealed cartridge bottom bracket: serviceable type bottom bracket that utilizes Conrad bearings

Seat tube angle: angle of the seat tube relative to a horizontal plane

Seat tube length: the length of the frame tube that houses the seatpost. Can be measured from the center of the bottom bracket shell to the center of the top tube, the top of the top tube, or the top of the seat collar

Self extracting crank bolt: type of crank bolt that utilizes a shoulder bolt and aluminum dust cap, eliminating the need for a crank extractor

Semi-integrated headset: headset assembly that utilizes bearing cups that are pressed into the head tube of the frame that allow the bearings to be located inside the head tube

Shock body: cylindrical tube of a rear shock that contains the damper

Side pull brake: any type of brake that is actuated from the side

Single pivot brake: type of caliper brake that utilizes a central pivot mechanism

Slider: the lower leg of a telescopic fork

Soldering: same as brazing, but below 800° F

Spike: A suspension phenomenon that results when a force tries to move oil through the piston on the compression stroke faster than the system's ports will allow, causing a jarring impact to the rider

Spindle: a short, slender or tapered shaft. Used in pedals and bottom brackets

Spline crank: type of crank arm that is designed to be used with a spline interface bottom bracket spindle

Splined spindle: type of bottom bracket spindle that utilizes splines on each end for the engagement with the crank arms. Spline count can range from 8 to 48 but must match the spline count of the bottom bracket exactly.

Spoke: one of the rods or braces that connects the hub and the rim of a wheel

Square taper crank: type of crank arm that is designed to be used with a square taper bottom bracket spindle.

Square taper spindle: type of bottom bracket spindle in which the ends are four sided. Incorporates a slight taper, usually 2°

Stanchion tube: the upper (stationary) tube of a telescopic fork. Usually houses the damper and spring assemblies

Star-fangled nut: nut assembly, specific to a threadless headset, that is driven into the steerer tube to allow for bearing adjustment. This device is not intended to be used with carbon fiber steerer tubes

Static spoke: a spoke that stabilizes the pulling spoke as the wheel rotates

Steel: iron based alloy containing up to 2% carbon

Steerer tube: the section of the fork connecting the crown and fork legs to the headset and stem, routed through the head tube of the bicycle frame

Stem length(extension): The distance from center of the stem's steerer tube clamp (or quill in a threaded system) to the center of the stem's handlebar clamp

Stem reach: When mounted on a bicycle, the horizontal distance from the center of the stem's handlebar clamp to the center of the fork steerer tube

Stem rise: - When mounted on a bicycle the vertical distance between the center of the steerer tube clamp and the center of the stem's handlebar clamp. Often expressed by manufacturers as the angle between the horizontal and the center line of the stem's extension

Stiction: combination of forces, static and friction, that prevents a shock from compressing easily

Straight gauge: tube which has a constant wall thickness over its entire length. A rod or spoke that has the same external dimension over its entire length

Strain: measure of the relative change in the shape or size of an object

Stress relieving: process of relieving unwanted spoke stress that is encountered during the wheel building process, usually from spoke wind-up

Stress riser: notch, hole, or other discontinuity in contour or structure which causes localized stress concentration

Swaging: metal forming technique in which the metal is plastically deformed at normal temperature to its final shape. In a bicycle components, two parts loosely fit together, and a mechanical or hydraulic tool compresses and deforms the fitting, creating a permanent joint. Often used to manufacture inexpensive steel hubs

Symmetrical lacing: pattern of lacing a wheel in which the head orientation of the spoke on one hub flange is a mirror image of that on the other side of the hub shell.

Tangential lacing: spoke lacing pattern where the spokes exit the hub flange tangent, or at an angle, to the centerline

Tapered steerer tube: steerer tube that has an external dimension that decreases from the crown race to the stem clamping area requiring two different sized headset bearings

Tension pulley: the lower pulley located in a rear derailleur cage that is tasked with taking up chain slack, or tensioning the chain, in a geared drivetrain

Tensioning: the process of incrementally adding tension to the spokes of a wheel

Three piece crank: type of crankset in which the two crank arms are separate from the bottom bracket spindle

Thru axle: large hollow hub axle that passes "thru" the hub and is not permanently attached, either front or rear, that increases stiffness and promotes better wheel tracking

TIG welding: an acronym for Tungsten Inert Gas welding, in which an arc from a non-combustible tungsten electrode radiates heat onto the work surface, to create a weld puddle in a protective atmosphere provided by a flow of inert shielding gas

Titanium: a light strong grey lustrous corrosion-resistant metallic element used in strong lightweight alloys

Toe-in: setting the fore and aft placement of a brake pad so that the leading edge contacts the braking surface prior to the trailing edge, usually having an initial gap at the trailing edge of the pad of 0.5 - 1.5mm

Tool chatter: phenomenon occurring during a machining process, cause by inadequately rigid fixturing, resulting in a rough, inconsistent, or wavy surface

Top cap- headset: on a threadless headset, the part that sits on top of the stem and supports the headset preload bolt

Top cap- suspension: on a suspension fork, the cap of the stanchion tube that threads into it at the crown and allows access to the internal parts of the shock.

Top out: the fully extended travel of a shock, often accompanied by an abrupt sound

Top tube length: measurement taken from the centerline of the head tube to the centerline of the seat tube along a horizontal line

Torque: a force applied to induce rotation

Torque wrench- beam type: the simplest form of torque wrench consists of a long lever arm between the handle and the wrench head, made of a material which will bend elastically a little under the applied torque. A second smaller bar carrying an indicator is connected back from the head in parallel to the lever arm. This second arm is under no strain at all, and remains straight. A calibrated scale is fitted to the handle, and the bending of the main lever causes the scale to move under the indicator

Torque wrench- click (micrometer) type: more sophisticated tool for measuring force applied to a fastener. At the point where the desired torque is reached, the clutch slips, signaling the desired torque has been reached. The most common form uses a ball detent and spring, with the spring preloaded by an adjustable screw thread, calibrated in torque units. The ball detent transmits force until the preset torque is reached, at which point the force exerted by the spring is overcome and the ball "clicks" out of its socket

Torx fastener: Type of screw head characterized by a 6-point star-shaped pattern, designed to match with modern torque limiting mechanical drivers

TPI (threads per inch)- fasteners: Measurement of a thread on a nut or bolt which counts the total number of threads over a one inch distance

TPI (threads per inch)- tire casing: Number of threads contained in one square inch of fabric, such as in a tire casing

Transverse cable: Cable that spans cantilever brake arms and links it to a central brake cable. Also referred to as a straddle cable

Tread: The rubber on the tires circumference that makes contact with the road or trail

Truing: The process of adding or decreasing tension to the spokes in a wheel so that it is laterally straight, radially round and the rim is centered between the locknuts of the hub

Tubeless (U.S.T.): Tire/wheel system that eliminates the use of an inner tube. The tire and rim have a specific hook profile and the sidewall of the tire is thicker to combat air lose

Tubular/sew-up: Tires that have the inner tube permanently stitched inside the casing. They are held in place using glue or glue-tape, and are affixed to rims which lack the sidewalls characteristic of a hook-bead rim

Two piece crank: Type of crank in which the spindle is permanently attached to one of the crank arms

U-brake: Type of center-pull brake that mounts directly to 8.9mm frame bosses. Found on BMX bikes and older mountain bikes

Uniform depth of thread: When building a wheel, the point at which all of the spoke nipples are threaded on to an equal depth, and the nipples are square with the side-wall of the rim

Vernier caliper: Caliper used to measure internal dimensions, external dimensions, and depending on the manufacturer, depth measurements by the use of a probe that is attached to the movable head and slides along the centre of the body. This probe is slender and can get into deep grooves that may prove difficult for other measuring tools.

Viscosity: The resistance of a substance to flow

Work-harden: Increased hardness of a metal due to deformation

Yield strength: The amount of stress at which a material exhibits a specified deviation from proportionality of stress and strain